State of California
THE RESOURCES AGENCY
Department of Water Resources

BULLETIN No. 83

KLAMATH RIVER BASIN INVESTIGATION

JULY 1964

HUGO FISHER
Administrator
The Resources Agency

EDMUND G. BROWN
Governor
State of California

WILLIAM E. WARNE
Director
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NOTE

More detailed studies of the Shasta Valley area were made subsequent to the investigation reported on in this bulletin. The results of the later studies are summarized in Bulletin No. 87, "Shasta Valley Investigation", dated July 1964.

Accordingly, the summaries, conclusions, and recommendations in Chapter V of this report as they apply to Shasta Valley may, in some cases, be superseded by information published in Bulletin No. 87.

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HUGO FISHER
Administrator
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Director
Department of Water Resources

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E OF CALIFORNIA—RESOURCES AGENCY WILLIAM E. WARNE, Director

PARTMENT OF WATER RESOURCES
BOX 388
RAMENTO

June 1, 1964

Honorable Edmund G. Brown, Governor
and Members of the Legislature
of the State of California

Gentlemen:

Bulletin No. 83, "Klamath River Basin Investigation", reports on a Department of Water Resources investigation authorized by the Legislature in Item 268.5, Chapter 3, Statutes of 1952.

Bulletin No. 83 was first published in May 1960. The preliminary report showed estimates of present and probable ultimate water requirements for irrigation, domestic, and industrial use based on full development of the natural resources of the Klamath River Basin. It contained an inventory of the water resources of the basin and presented a master plan for water development capable of furnishing water supplies to areas of potential need within the basin. This plan was intended to serve as a general guide to future definitive studies of local water development.

On December 18, 1963, in Yreka, the California Water Commission and the Department of Water Resources jointly held a public hearing on the preliminary edition of Bulletin No. 83 to receive comments from all interested agencies, group, and individuals. This final edition of Bulletin No. 83 reflects the comments received at the public hearing, and includes a brief statement concerning technical and editorial changes necessary to finalize the report. In other respects, its content and intent are the same as in the preliminary edition.

The Klamath River, discharging an average of more than 12,000,000 acre-feet of waters annually into the Pacific Ocean, is one of the significant sources of water being considered to meet future water deficiencies throughout the State. This report is of value in delineating present and future water demands for which provision must be made prior to exporting water from the Klamath River Basin.

Information and data developed by the investigation were used in the preparation of The California Water Plan, in the formulation of the Klamath River Compact, and in further detailed investigation of water development projects in Shasta Valley.

Sincerely yours,

William E. Warne

Director

ACKNOWLEDGMENTS

Valuable assistance to, and data used in this investigation have been contributed by agencies of the Federal Government, cities, counties, public districts, and by private individuals and companies. This cooperation is gratefully acknowledged.

Special mention is made of the helpful cooperation of the following:

State of Oregon

County of Siskiyou

Montague Water Conservation District

Siskiyou Soil Conservation District

Butte Valley Soil Conservation District

Agricultural Agent, Klamath County, Oregon

Department of Fish and Game, State of California

Bureau of Reclamation, United States Department of the Interior

Corps of Engineers, United States Army

Geological Survey, United States Department of the Interior

Forest Service, United States Department of Agriculture

Farmers resident in Scott, Shasta, and Butte Valleys, who aided in the soil moisture depletion and ground water studies.

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

EDMUND G. BROWN, Governor

HUGO FISHER, Administrator, The Resources Agency

WILLIAM E. WARNE, Director, Department of Water Resources

ALFRED R. GOLZE, Chief Engineer

JOHN R. TEERINK, Assistant Chief Engineer

NORTHERN BRANCH

John M. Haley .... Chief

The investigation was conducted and the preliminary edition of the report dated May 1960 was prepared under the direction of

William L. Horn .... Principal Engineer

by

Robert B. Bond .... Supervising Engineer
Stuart T. Pyle .... Supervising Engineer

Assisted by

B. H. Hoffmaster .... Senior Engineer
Helen J. Peters .... Associate Engineer
Edwin J. Barnes .... Senior Engineer
Blair T. Bower .... Assistant Engineer
Russell Franson .... Assistant Engineer

Special Assistance by

Robert G. Eiland .... Principal Engineer
M. Guy Fairchild .... Supervising Engineer
Charles F. Kleine .... Senior Engineer
John W. Shannon .... Supervisor, Land and Water Use Section
Robert T. Bean .... Supervising Engineer Geologist
Wilfred W. Peak .... Senior Engineering Geologist
John L. James .... Supervisor of Drafting Services
Roy N. Haley .... Senior Land and Water Use Analyst
Sam L. Stringfield .... Senior Engineer
Jack G. Wulff .... Senior Engineer
J. Preston Cedarholm .... Associate Engineer
Steven H. Chan .... Associate Engineer
Thais U. Johnson .... Assistant Hydraulic Engineer
Donald A. Ralph .... Assistant Hydraulic Engineer

Studies of fish and wildlife problems were conducted in cooperation with the California Department of Fish and Game

Walter T. Shannon .... Director
Jack Fraser .... Water Projects Coordinator
Richard J. Hallock .... Fisheries Biologist IV
David E. Pelgen .... Fisheries Biologist IV
Leonard O. Fisk .... Fisheries Biologist III

Studies of ground water geology were conducted in cooperation with the United States Department of the Interior, Geological Survey, Ground Water Branch

Joseph F. Poland .... Research Geologist
Perry Wood .... Geologist
Seymour Mack .... Geologist

ORGANIZATIONAL CHANGES

The Klamath River Basin Investigation was conducted from 1952 to 1956 under the direction of the former State Water Resources Board by the former Division of Water Resources, Department of Public Works.

A. D. Edmonston, (now deceased) was State Engineer and Secretary of the former Water Resources Board until the time of his retirement on November 1, 1955. He was succeeded by Harvey O. Banks who served as State Engineer until that office was abolished by July 5, 1956; at which time the Department of Water Resources was created and Mr. Banks was appointed as director.

William E. Warne succeeded Mr. Banks who resigned from the Department to enter private consulting business on January 1, 1961.

In July 1962, the Department of Water Resources was placed organizationally in the newly created Resources Agency of California. Mr. Warne was appointed acting administrator to the Resources Agency in addition to continuing as Director of the Department of Water Resources. Mr. Hugo Fisher was appointed Administrator of the Resources Agency in January 7, 1963.

This investigation was carried out under the general direction of William L. Berry who was in charge of planning in the former Division of Water Resources and Chief of the Division of Resources Planning in the Department of Water Resources subsequent to July 5, 1956.

CALIFORNIA WATER COMMISSION

RALPH M. BRODY, *Chairman*, Fresno [1]

WILLIAM H. JENNINGS, *Vice Chairman*, La Mesa

JOHN W. BRYANT, Riverside

JOHN P. BUNKER, Gustine

IRA J. CHRISMAN, Visalia

JOHN J. KING, Petaluma

EDWIN KOSTER, Grass Valley [2]

NORRIS POULSON, La Jolla [3]

MARION R. WALKER, Ventura

WILLIAM M. CARAH, *Executive Secretary*

ORVILLE ABBOTT, *Engineer* [4]

Changes in membership of California Water Commission after publication of preliminary edition.

[1] Appointed 1/19/61 succeeding James K. Carr, Sacramento
[2] Appointed 2/14/63 succeeding George Fleharty, Redding
[3] Appointed 4/4/62 succeeding Samuel B. Morris, Los Angeles
[4] Appointed 12/1/63 succeeding George Gleason

Mt. Shasta as seen from Shasta Valley. Lake Dwinnell in foreground

PUBLIC HEARING

on

Preliminary Edition

of

Bulletin No. 83, Klamath River Basin Investigation

In conformance with the Water Code and the Department of Water Resources policy, a public hearing was held on December 18, 1963, in Yreka, California, to receive comments from interested agencies, groups, and individuals on the preliminary edition of Bulletin No. 83, "Klamath River Basin Investigation." The hearing was attended by about 20 persons, including local ranchers, farmers, and representatives of federal, state, and local governmental agencies.

The following paragraphs present brief statements made by representatives from federal, state, and local governmental agencies, and from local individuals concerning the preliminary report.

Mr. Kenneth G. Baghott, Tulelake Farm Advisor, presented a brief statement regarding estimates of water requirements made by the University of California Agriculture Extension Service for the Tulelake area. He pointed out that estimates of consumptive use for certain crops in Bulletin No. 83 are slightly less than estimates by the University, and suggested that these figures be checked and adjusted. A review of Mr. Baghott's written statement revealed that the differences in these estimates of consumptive use of applied water amounted to less than 7 percent of the total water requirements for the Tulelake area.

Mr. Edwin V. Lance, Manager of the Tulelake Irrigation District, submitted comments on behalf of the district. He compared estimates of water requirements for the Tulelake Irrigation District based on Bulletin No. 83 unit use values with estimates by the University and the average annual water deliveries by the district. In his opinion, Bulletin No. 83 estimates are slightly low because they do not include water necessary to leach out salts prior to the irrigation season. However, a review of Mr. Lance's written comments revealed that the department's estimates of water requirements based on a irrigation efficiency of 55 percent is only about 2 percent less than the district's average annual deliveries. Mr. Lance stated that his district is in firm agreement with the summary, conclusions, and recommendations of Bulletin No. 83, and recommends that water requirements be reviewed periodically as new data become available.

Mr. M. V. Maxwell, Chairman, Siskiyou County Water Resources Board, stated that his board is very much in agreement with Bulletin No. 83 in most respects. However, he commented that estimates of unit values of consumptive use shown for certain crops are somewhat low. Also, irrigation efficiencies shown in the bulletin appear to be higher than the economy can bear. Siskiyou County's estimates for ultimate water requirements are approximately the same as the estimates shown in Bulletin No. 83.

Mr. Maxwell also commented on the estimate of ground water yield for Scott Valley. His board feels that Bulletin No. 83 estimate is high, based on the experience of wells drilled since the field studies were made.

On the basis of review of both verbal and written comments received at the hearing, and written comments received by mail, it appears that no significant disagreements exist over the information presented in Bulletin No. 83. The objectives of the investigation appear to be substantially accomplished. It was concluded, therefore, that no technical and only minor editorial changes were needed for the final edition of the bulletin. Moreover, it should be pointed out that the Department of Water Resources will, in the future, be making coordinated statewide planning studies of the Klamath River Basin, which will involve a reevaluation of water requirements of that basin, based on more reliable and up-to-date data, at which time revisions of water requirements will be made if such studies form sufficient basis for doing so.

Copies of the transcript of the December 18, 1963, hearing are on file with the Department of Water Resources in Sacramento and are available for review by the public. An office report was prepared, setting forth the department's response to all written comments received. The report is available for limited distribution and is also on file for review by the public.

Verbal comments were made at the hearing by the following persons:

- Mr. M. V. Maxwell, Chairman, Water Resources Board, Siskiyou County
- Mr. Kenneth G. Baghott, Agriculture Extension Service, University of California, Tulelake Farm Advisor
- Mr. Ed Lance, Manager, Tulelake Irrigation District
- Mr. Delos Mills, President, Butte Valley Water Development Association

Written comments were received from the following:

State Department of Fish and Game
North Coastal Regional Water Pollution Control Board
Siskiyou County Board of Supervisors
State Department of Public Works, Division of Highways
Tulelake Irrigation District
Tulelake Farm Advisor

CHAPTER I

INTRODUCTION

The Klamath River Basin, occupying a large part of northwestern California and south central Oregon, extends across California from within a few miles of the Nevada border to the Pacific Ocean. Two-thirds of the basin is in California and one-third in Oregon. The basin in California includes all or parts of the Counties of Modoc, Siskiyou, Del Norte, Trinity, and Humboldt. The average seasonal flow of the Klamath River into the Pacific Ocean is about 12,500,000 acre-feet, over 18 per cent of the combined flow of all water producing areas of the State.

The Klamath River rises in Oregon, where it is formed by the Wood, Williamson, and Sprague Rivers. In California, the river is joined by the Shasta, Scott, Salmon, and Trinity Rivers. During its course to the sea, only moderate use is made of Klamath River waters. In both Oregon and California, irrigation is the largest use of water. Approximately 500,000 acres within the basins are irrigated and about 16,000 acres devoted to urban, domestic, and other uses. These present uses made of the waters of the river, however, do not appreciably decrease the natural flow from the basin. For the most part, this potential water resource remains in its natural state. One of the most important uses made of the stream, although nonconsumptive, is the habitat provided for anadromous fish, the salmon and steelhead that return from the ocean to fresh water to complete their life cycle. The power potential of the stream is also relatively undeveloped. Approximately 133,000 kilowatts of installed power capacity are located in the upper reaches of the basin.

Tremendous population increases, and the accompanying expansion in agriculture and industry since the close of World War II, have depleted local water supplies in the central and southern portions of the State. The large seasonal overdraft of the available water supplies in these water deficient areas of the State have occasioned extensive water resource investigations. These water deficient areas from economic necessity have forced consideration of plans for importing waters from areas of general surplus to supplement their rapidly diminishing supplies. As pressure for such transfer of water has increased, it has become apparent that the water needs of the northern areas should first be determined and provisions made for their satisfaction to prevent the detrimental effects which would result from indiscriminate and excessive export.

The California Water Plan is a master plan for the future development of the water resources of the State, providing for the fullest practicable measure of conservation, protection, control, distribution, and utilization of the water resources, both surface and underground, in order to meet the present and future water needs for all beneficial purposes in all areas of the State. The California Water Plan was published as Bulletin No. 3 of the Department of Water Resources in May, 1957.

The full development and use of the water resources of California requires a thorough knowledge of the location and extent of those resources. An inventory of the waters of the Klamath River Basin which are available for development and utilization within California must take into account the fact that the Klamath River is an interstate stream shared by Oregon and California. The waters originating within the basin are subject to use by both States, and the amount available for use in either state is affected by the uses in the other.

It has been recognized that competent plans for the development of the waters of the Klamath River Basin for the maximum benefit of both Oregon and California depends upon the successful resolution of problems created by the interstate character of the stream. Toward this objective, the Legislatures of both California and Oregon, in 1953, established within each State, a commission whose primary function was to cooperate with the similar commission in the formation of an interstate compact relating to the distribution and use of the waters of the Upper Klamath River Basin. The two commissions negotiated at length, and submitted to their respective legislatures a compact, which was thereafter accepted by each state. Subsequently, the Congress of the United States has consented to the compact and it is now in effect the "law of the river."

AUTHORIZATION FOR INVESTIGATION

On November 2, 1951, State Senator Randolph Collier requested that the then State Water Resources Board make a preliminary survey of the water resources of Siskiyou and Modoc Counties and the Klamath River Basin, with the objective of determining the scope and cost of a comprehensive basin investigation. The former Division of Water Resources made such an investigation, and concluded in its report to the State Water Resources Board that any comprehensive study of the Klamath River should include the entire basin. It was estimated that an adequate program of investigation would take about three years to complete.

The recommendation for a three-year investigation was adopted by the State Water Resources Board and

in the Budget Act of 1952, the Legislature provided an appropriation to the State Water Resources Board in the amount of $50,000 for "a comprehensive survey of the water resources of the Klamath River Basin." On July 19, 1952, the State Water Resources Board approved a proposed work program and directed the Division of Water Resources to proceed with the investigation. Subsequently, the Legislature made an additional appropriation of $71,243 in 1953, and an appropriation of $71,340 in 1954.

SCOPE OF KLAMATH RIVER BASIN INVESTIGATION

The Klamath River Basin Investigation included the following studies: (1) an inventory of available water supplies, both surface and underground; (2) a determination of present and ultimate water requirements, predicated upon the full development of all natural resources; (3) an estimate of the effect on available water supplies resulting from full development of all natural resources, and from placing under irrigation all lands potentially capable of such development; (4) a determination of areas within the basin now having, or ultimately facing, a deficiency in water supply; and (5) an inventory of possible plans for local projects that would provide ample water supplies for all uses within the basin.

The Klamath River is one of California's major streams, both in the geographical extent of the drainage basin and in quantity of runoff. The surplus waters available in the Klamath River are an important consideration in any comprehensive plan for development of the water resources of the State. Consequently, this investigation was closely related to, and coordinated with, the statewide investigation which resulted in the formulation of The California Water Plan.

Field work on the Klamath River Basin Investigation commenced in August, 1952. During the investigation, available precipitation and runoff records were collected, and additional precipitation and stream gaging stations were installed and operated in order to expand and extend the coverage of existing records.

The mineral quality of surface and ground waters was studied in order to evaluate the suitability of the water supplies for agricultural and other beneficial uses, and to locate areas in which water supplies were subject to mineral degradation.

Geologic field surveys and investigations provided data used in delineating the approximate areal extent of ground water basins, and in estimating the storage capacity, potential yield, and susceptibility of such basins to development. During the investigation, well logs were collected and analyzed, and ground water levels were determined through periodic water level measurements at selected wells. Field surveys, including geologic examinations, were made to locate and evaluate the suitability of possible dam and reservoir sites.

A detailed land use survey of the entire basin, except for the area within the Klamath Indian Reservation, was made in 1953 to ascertain present land use patterns and water use practices. This survey also served as a guide in forecasting a pattern of probable ultimate land use. Needed information pertaining to Indian lands was furnished by the United States Bureau of Reclamation.

In order to estimate future water requirements in the investigation area, lands in the basin were classified as to their suitability for irrigated agriculture. The original land classification was made in 1952 and 1953, and was reviewed and modified in 1955 in conformity with standards adopted for the Northeastern Counties Investigation. The modified results have been included in the Department of Water Resources, preliminary edition of Bulletin No. 58, "Northeastern Counties Investigation".

Accordingly, it was determined that field investigations, classification of lands, the making of crop surveys, and the determination of consumptive use factors for those portions of the Klamath River Basin located in Oregon were both pertinent and necessary to this investigation. Such field activities were carried out with the full knowledge and consent of appropriate officials in the State of Oregon, and in cooperation with the United States Bureau of Reclamation. Additionally, information and data developed during this investigation proved to be of exceptional value and pertinence to the deliberations and conclusions of the Klamath River Compact Commissions of Oregon and California.

Considerable attention was given to the determination of unit values of consumptive use of water for irrigated crops. All available data were assembled and reviewed, and field studies conducted to measure consumptive use. The studies consisted of sampling the soil moisture content of irrigated fields, throughout the growing season to determine the amounts of water used. The results of field studies were used to develop coefficients for the empirical Blaney-Criddle method of computing consumptive use. Use of water for urban and municipal purposes was evaluated from records of water use collected from most of the cities and smaller communities within the Klamath River Basin.

Current irrigation practices in Scott, Shasta, and Butte Valleys, and in the Klamath Project of the United States Bureau of Reclamation, were studied to determine quantities of water applied to major crops on lands of various soil types. Farm and service area efficiencies were determined by utilizing stream flow records, and diversion and farm delivery records maintained by irrigation districts, and records of the Bureau of Reclamation.

Data relating to present and ultimate land use, as well as estimates of present and ultimate water requirements in the basin, were published in preliminary form as the "Interim Report on Klamath River Basin Investigation, Water Utilization and Requirements", a report of the State Water Resources Board, dated March, 1954. The data and estimates presented in that report were preliminary in form and were published for the purpose of making the data available to interested agencies in both California and Oregon. These estimates have been reviewed and revised as a result of additional information and studies subsequent to that date.

Plans for developing water supplies to meet present and ultimate water requirements for all major irrigable areas were investigated. This phase of the investigation utilized much of the above-mentioned data. In general, the plans studied were large scale developments utilizing local water supplies. The engineering was preliminary in nature, and for the express purposes of determining where water could be developed, in what amounts, what areas could be served by the various projects, and what the approximate cost would be. In addition to investigating reservoirs for local water service, plans were studied of means of stabilizing the yield of the Upper Klamath River Basin to meet water needs in both Oregon and California. Separate projects were investigated to divert water from the Klamath River to serve lands in Butte Valley and Shasta Valley. For Scott Valley, development of both surface and ground water supplies were considered. In all cases, plans for water development studied under this investigation were coordinated with, and made a part of, The California Water Plan.

COOPERATION WITH OTHER AGENCIES

During the course of this investigation, the Department entered into cooperative agreements with the United States Geological Survey and the California Department of Fish and Game for services of a specialized nature which those agencies were particularly well equipped to furnish.

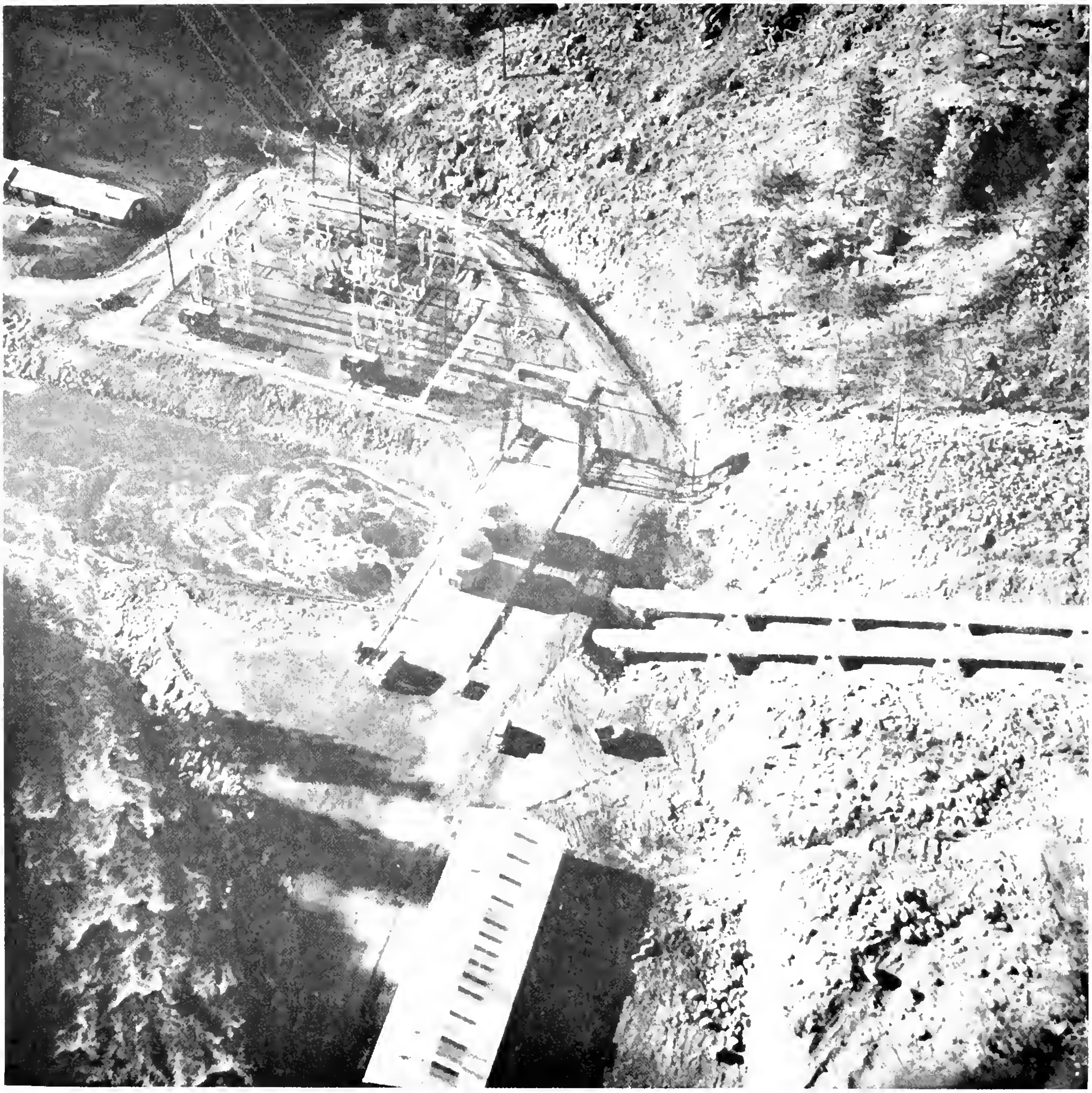
Accordingly, an agreement was made with the United States Geological Survey, whereby matching funds for ground water investigation, in the amount of $8,000 per year, were made available by the State for the fiscal years 1953-54 and 1954-55. These funds, matched by equal contributions from federal sources, were used to finance a reconnaissance survey covering the geology of ground water basins, the occurrence and movement of ground water and an estimate of the available underground storage capacity, in the principal ground water areas in Butte, Shasta, and Scott Valleys. Pertinent information resulting from these studies is contained in this bulletin. In October, 1956, the United States Department of the Interior published a preliminary report entitled "Natural Resources of Northwestern California", which includes the results of these studies. Results of the study in Scott Valley have been published in Water Supply Paper No. 1462, "Geology and Ground Water Features of Scott Valley, Siskiyou County, California". It is expected that final reports of the geologic investigations in Butte and Shasta Valleys will be published by the United States Geological Survey at a later date. Information regarding ground water basins in the Oregon portion of the Klamath River Basin was compiled during a similar investigation conducted under a cooperative agreement between the State of Oregon and the United States Geological Survey.

Additionally, an agreement between the State of California and the Surface Water Branch of the United States Geological Survey provided for additional field activities to supplement existing data on surface runoff in the Klamath River Basin. State funds in the amount of $4,500 were matched by funds of the Geological Survey to provide for the installation of additional stream gaging stations in the basin. These gaging stations, maintained by the Geological Survey, furnish stream flow records which, in the future, will permit a more complete evaluation of the surface water supply.

Water stage recorder stations installed under this agreement are located on Hayfork Creek, a tributary to the South Fork of the Trinity River, and on the Sprague River. A staff gage, observed intermittently, was installed on the Klamath River at Walker Bridge, but deactivated in October, 1954. In addition, eight crest-stage stations were established by the United States Geological Survey on tributary streams of the Klamath River, to provide short-term data for use in making estimates of runoff. These stations were:

- Beaver Creek near Walker Post Office
- Indian Creek near Happy Camp
- Elk Creek near Happy Camp
- South Fork of the Salmon River near Forks of Salmon
- North Fork of the Salmon River at Sawyers Bar
- Bluff Creek near Weitchpec
- South Fork of Trinity River at Forest Glen
- South Fork of Trinity River at Hyampom

Studies of water requirements for the preservation and propagation of fish and wildlife in the Klamath River Basin were made by the California Department of Fish and Game. In accordance with service agreements between the Division (now Department) of Water Resources and the Department of Fish and Game, biologists from the latter agency were assigned to gather data and conduct studies leading to coordination of water resource development with measures for the preservation and enhancement of the fisheries and wildlife resources. A report on the existing fishery and the wildlife resources of the Klamath River Basin, prepared by the Department of Fish and Game, is presented in Appendix D.



California Oregon Power Company photograph

The California Oregon Power Company Big Bend Project on the Klamath River. View looking down on powerhouse in center, penstocks on right, and substation and operators' cottages at upper left.

AREA UNDER INVESTIGATION

The Klamath River Basin lies in south central Oregon and northwestern California. It includes the drainage area contributing directly to the runoff of the Klamath River, plus the Lost River, Butte Valley, and Red Rock Valley basins. Butte and Red Rock Valleys in California have no surface outflow. Under natural conditions, Lost River had its terminus in Tule Lake, a natural sump without outlet. Presently, however, a portion of the flood flow of Lost River is diverted by gravity into the Klamath River in Oregon. The flows which reach Tule Lake are controlled within leveed areas and finally diverted into the Klamath River by pumping.

The Klamath River Basin has an area of approximately 10,010,000 acres, of which some 3,610,000 acres are in Oregon and 6,400,000 acres are in California. The area in Oregon comprises portions of Lake, Klamath, Josephine, and Jackson Counties; in California it includes portions of Modoc, Siskiyou, Trinity, Humboldt, and Del Norte Counties. The extent of the basin is indicated on Plate 1, "Location of Klamath River Basin."

The Williamson, Sprague, and Wood Rivers, rising in the extreme northern part of the basin, flow into Upper Klamath Lake. This lake is drained by the Link River, which flows through a short reach and enters Lake Ewauna at Klamath Falls. Lake Ewauna forms the headwaters of the Klamath River proper, from which the river flows southwesterly for a distance of some 263 miles to the California coast, entering the ocean at a point approximately 32 miles south of the Oregon-California boundary. The major tributaries of the Klamath River in California are the Shasta, Scott, Salmon, and Trinity Rivers. In addition, numerous minor streams complete the drainage net.

In order to facilitate determination of its present and probable future problems of water supply and development, the Klamath River Basin was divided into 12 major hydrographic units. The boundaries of these hydrographic units were drawn with consideration to factors of topography, water supply, and water utilization. The hydrographic units numbered 1 through 5, and the units numbered 6 through 12, are referred to in this bulletin as the Upper and Lower Basins, respectively.

For the most part each major hydrographic unit includes the entire drainage area of a single major tributary watershed or sub-basin. Exceptions are the Upper Klamath Lake Hydrographic Unit No. 3, which combines the Wood River drainage area with the area tributary to the west side of Upper Klamath Lake; the Lost River No. 4 and Klamath River No. 11 Hydrographic Units, which constitute the areas draining into the main stem of the Klamath River above and below Keno; and the Upper Trinity River and Lower Trinity River Hydrographic Units Nos. 9 and 10 which divide the drainage area of the main stem of the Trinity River into upper and lower sub-basins. Several of the major hydrographic units were further divided into subunits on the basis of geographic and geologic considerations which affect hydrologic analysis and planning for water supply development.

The northern part of the Klamath River Basin, lying mostly in Oregon, consists of a series of volcanic plateaus ranging in elevation from about 4,000 to 5,000 feet. The major portion of the drainage area above the stream gaging station on the Klamath River at Keno, Oregon, near the California-Oregon border, is included in these high plateaus. Most of the irrigated agricultural development in the Klamath River Basin has occurred in the valley portions of this plateau region. Much of this development is on land reclaimed by drainage of shallow lakes and swamps.

The remainder of the Klamath River Basin comprises a series of mountain ranges, running generally from northwest to southeast, separated by long, somewhat narrow valleys. Extensive valley areas in California are found in Butte, Shasta, and Scott Valleys. Hayfork, Hyampom, and Hoopa Valleys, somewhat smaller in extent, lie in the Trinity River drainage area.

Boundaries of each hydrographic unit and subunit are delineated on Plate 15, "Present and Probable Ultimate Water Service Areas." Areas of the Klamath River Basin, segregated in accordance with state, hydrographic unit, and subunit boundaries, are presented in Table 1. Areas segregated by counties within the two states are presented in Table 2.

Climate

The wide geographical extent of the Klamath River Basin contributes toward a wide variety of climatic conditions. With the exception of the Pacific coastal strip, which is subject to summer fog and mild wet winters, the climate is characterized by dry summers with high daytime temperatures, and wet winters with moderate to low temperatures. Conditions in local areas may, however, vary from the general mean. Mean seasonal precipitation generally exceeds 40 inches in depth on the coast, but decreases to less than 12 inches in areas of the eastern portion of the Basin. Local regions of very heavy rainfall exist in the Coast Range, where mean seasonal precipitation frequently exceeds 100 inches.

The growing season in the western coastal region averages about 260 days a year, with some years virtually frost-free. In the higher inland areas the growing season is shorter, and in the northeastern part of the Basin averages only 100 days or less. Where the growing season is so short, killing frosts may be experienced in any month of the year. Table 3 contains a summary of pertinent climatological data for stations in, or adjacent to, the Klamath River Basin.

TABLE 1

AREAS OF HYDROGRAPHIC UNITS AND SUBUNITS WITHIN THE KLAMATH RIVER BASIN

(In acres)

Reference number	Name	Area in Oregon	Area in California	Total area
1	Williamson River	945,200		945,200
2	Sprague River	980,900		980,900
3	Upper Klamath Lake			
3A	Wood River	210,100		210,100
3B	Klamath Lake	248,100		248,100
	Subtotals	458,200		458,200
4	Lost River			
4A	Swan Lake	93,100		93,100
4B	Clear Lake	294,700	463,500	758,200
4C	Klamath Project	458,400	139,600	598,000
4D	Lava Beds		358,000	358,000
4E	Oklahoma		128,600	128,600
	Subtotals	846,200	1,089,700	1,935,900
5	Butte Valley			
5A	Macdoel	16,000	168,700	184,700
5B	Butte Creek		152,400	152,400
5C	Red Rock		66,700	66,700
	Subtotals	16,000	387,800	403,800
6	Shasta Valley			
6A	Yreka		39,900	39,900
6B	Little Shasta		125,700	125,700
6C	Gazelle-Grenada		98,100	98,100
6D	Big Springs-Juniper		114,900	114,900
6E	Grass Lake		18,000	18,000
6F	Parks Creek		33,000	33,000
6G	Upper Shasta River		77,800	77,800
	Subtotals		507,400	507,400
7	Scott Valley			
7A	East Side		86,800	86,800
7B	Moffett Creek		79,100	79,100
7C	Quartz Valley		43,700	43,700
7D	West Side		112,900	112,900
7E	Callahan		101,000	101,000
	Subtotals		423,500	423,500
8	Salmon River			
8A	Wooley Creek		96,500	96,500
8B	North Fork of Salmon		156,700	156,700
8C	South Fork of Salmon		222,000	222,000
	Subtotals		475,200	475,200
9	Upper Trinity River		467,400	467,400
10	Lower Trinity River		858,700	858,700
11	Klamath River			
11A	Copco	170,400	66,300	236,700
11B	Hornbrook	168,900	75,600	244,500
11C	Ager		96,500	96,500
11D	Happy Camp	23,700	1,061,600	1,085,300
11E	Mouth of Klamath		320,200	320,200
	Subtotals	363,000	1,620,200	1,983,200
12	South Fork of Trinity River			
12A	Hyampom		402,600	402,600
12B	Hayfork		167,800	167,800
	Subtotals		570,400	570,400
	TOTALS, KLAMATH RIVER BASIN	3,609,500	6,400,300	10,009,800

TABLE 2

AREAS OF COUNTIES WITHIN THE KLAMATH RIVER BASIN

(In acres)

State and county	Area	
Oregon		
Lake	332,700	
Klamath	3,113,100	
Jackson	160,100	
Josephine	3,600	
Subtotal	3,609,500	
California		
Modoc	752,600	
Siskiyou	3,270,400	
Trinity	1,635,600	
Humboldt	600,200	
Del Norte	141,500	
Subtotal	6,400,300	
TOTAL, KLAMATH RIVER BASIN		10,009,800

TABLE 3

GENERAL CLIMATOLOGICAL DATA AT SELECTED STATIONS IN OR ADJACENT TO THE KLAMATH RIVER BASIN

Location of station	Elevation, in feet	Approximate length of growing season, in days	Maximum and minimum temperature for period of record, in degrees Fahrenheit		Mean seasonal depth of precipitation, in inches
			Maximum	Minimum	
Oregon					
Chiloquin	4,200	106	104	—24	17.02
Klamath Falls	4,190	157	105	—24	12.93
California					
Tulelake	4,036	130	99	—25	8.80
Macdoel	4,250	119	103	—15	12.87
Yreka	2,625	182	112	—11	18.12
Fort Jones	2,747	163	108	—22	20.79
Weaverville	2,050	175	116	—5	36.21
Orleans	423	225	117	8	50.00
Klamath	25	207	89	24	98.93

Soils

Soils of the Klamath River Basin vary markedly in type, composition, depth, and other physical and chemical properties, in accordance with differences of parent material, nature of deposition, alluviation, and age and degree of development. In general, the soils can be divided into five broad groups as follows:

(1) *Residual soils* which have been developed in place by disintegration and weathering of the underlying consolidated rocks, and are of both sedimentary and basic igneous origin;

(2) *Old valley fill soils* have undergone marked changes since their deposition, and are composed largely of eroded materials from surrounding hills within each valley;

(3) *Recent alluvial soils,* derived from sediments that have undergone little or no change in physical or chemical properties since their deposition;
(4) *Lacustrine or basin deposit soils,* largely formed from lake sediments, some of which have undergone pronounced changes of profile characteristics since their deposition; and
(5) *Organic soils,* derived mainly from deposition of organic materials under marshy conditions.

Residual soils occur mainly on hill and mountainous areas surrounding the valley floor lands. The soil depth varies from very shallow scabland with considerable rock present on the surface and throughout the profile, to lands having good depth of soil and with little or no rock present. Drainage is generally good and moisture retention is adequate in the deeper soils. Wherever topographic conditions are suitable, certain of these soils can be utilized for crop production. Only a small portion of the gross area of the irrigable lands, however, is composed of residual soils.

Soils derived from old valley fill occur on sloping remnants of old alluvial fans. Soil-forming processes have brought about marked changes within the profile during the period following the deposition of the unconsolidated materials from whence these soils are derived. The surface horizon is leached and the subsoil shows an accumulation of clay, a concentration of lime, and in some places a cemented hardpan. These soils are generally found at elevations lying between the residual and Recent alluvial groups. They vary in agricultural importance in accordance with soil depth and the presence of rock. Their crop adaptability is normally limited to shallow-rooted crops.

Recent alluvial soils generally have smooth and gently sloping topographic features. They occur to the greatest extent along the main stem of the Scott, Shasta, Lost, and Sprague Rivers. Smaller areas are found adjacent to other major and tributary stream channels. In general, these soils are deep, friable, and medium-textured, and are well suited for all climatically adapted crops.

Soils derived from lacustrine deposits occur in Butte, Swan Lake, Shasta, and Lost River Valleys, and in the vicinity of Lower Klamath Lake. These soils have developed from fine sediments carried by streams into fresh-water lakes. They are normally fine-textured, with fairly compacted subsoils. In some areas, due to restricted or limited drainage, accumulation of saline and alkaline salts has occurred.

Local drainage improvements have brought about the reclamation of some lands having alkaline lacustrine soils, but large areas remain in which the usability of these soils has not been determined. Consequently, the alkaline lacustrine soils were not classified as potentially irrigable. Lacustrine soils, with adequate facilities for drainage, are well suited to climatically adapted medium- and shallow-rooted crops.

Within the Wood River Valley, and in the vicinity of Lower Klamath and Tule Lakes, there are large areas of soils principally derived from the decomposition of organic materials. In general, these soils are highly productive when reclaimed by adequate drainage. They are normally deep, medium to fine-textured, and suited to a wide variety of climatically adapted crops.

Geology

The Klamath River Basin includes parts of three of the principal geomorphic provinces of the Western United States. Geomorphic provinces are areas characterized by like earth forms and usually by similar geologic features. The three provinces represented within the Klamath River Basin are, from east to west, the Modoc-Oregon Lava Plateau, the Cascade Range, and the Klamath Mountains. The Modoc-Oregon Lava Plateau includes nearly all of the Klamath River Basin in California east of, and including, Butte Valley. The Cascade Range forms a north-south belt through the basin, extending from beyond Crater Lake on the north to Mt. Shasta on the south. It is bounded in part on the east by the western edge of Butte Valley and on the west by the western edge of Shasta Valley. The Klamath Mountains province includes the entire remainder of the basin lying west of the Cascade Range. A more extensive description of the geology of the Klamath River Basin appears in Appendix A.

Present Development

Within the past 100 years the Klamath River Basin has developed from a primitive, little-known mining region into one of the leading timber producing areas of the nation. In addition, it has developed an important agricultural economy, and is gaining increasing prominence for its recreational opportunities. The settlement of the basin by white men dates from the time gold was first discovered in Trinity County in 1848. While the mining of gold was the original lure to immigration and development, it was eventually found that the vast timber stands, the rich agricultural lands, and the recreational potential were of far greater value. Today a stable and expanding economy is based upon these resources. Further development of the mineral resources of the basin, at present largely dormant, may occur in the future.

As miners became more plentiful in the early 1850's, and as the readily available gold became scarcer, some of the settlers started raising staple commodities such as corn, wheat, and beef for the increasing population. Later it was found that fertile valley areas along the Scott and Shasta Rivers were adaptable to the growing of irrigated crops, such as cereals and diversified truck products, and many of the early large stock

ranches were gradually subdivided into smaller ranches and farms.

Many of the old mining ditches built in the early 1850's are now used for irrigation. The most notable example of this conversion is the Yreka Ditch, which diverts water from the Shasta River at the confluence of Eddy and Dale Creeks. This ditch, winding northward along the west side of Shasta Valley, was built to bring water to the area around Yreka for placer mining operations. The ditch, originally about 90 miles in length, terminated in the vicinity of Hawkinsville. Today, a portion of the ditch about 15 miles in length is used to carry water from Dale and Eddy Creeks, plus diversions from Willow and Parks Creeks, to irrigate a considerable acreage of land in the vicinity of Gazelle.

In 1905, the United States Reclamation Service, now the Bureau of Reclamation, began to reclaim and develop for irrigation the lands of the upper Klamath Basin now included in the Klamath Project. Construction of such works as Clear Lake Dam, Gerber Dam, Link River Dam, and many miles of canals, together with drainage of Tule Lake, has provided for the irrigation of the largest, and one of the most fertile, agricultural areas in the basin.

During the period from 1900 until the late 1920's there was a great diversification of crops grown within the basin, although the fruit and vegetables grown at that time were mainly for local consumption. As transportation facilities gradually improved, an increasing outside market for hay, beef, and dairy products induced greater production of these items, and resulted in the dwindling of acreages planted to orchards and row crops.

At the present time, hay, grain, and forage crops, and cattle raising account for the largest percentage of developed agricultural lands. In the Oregon portion of the Klamath River Basin, and to a limited extent in Modoc and Siskiyou Counties in California, high water table lands and marsh areas support a large acreage of native pasture not dependent upon surface application of water for growth. Potatoes, produced in the Klamath Project, and to an increasing extent in Butte Valley, are now among the leading agricultural commodities of the region.

The lumber industry in the Klamath River Basin has grown from a limited early role as a supplier of needs of the local miners to a leading position among the lumber producing facilities of the nation. Large untouched stands of pine and fir assure that the lumber industry will continue to be of major importance for many years to come. With proper timber management, the industry will continue at its present level into the indefinite future. This industry presently includes the manufacture or remanufacture of rough lumber, finished lumber, and timber by-products. The manufacture of timber by-products, such as plywood and hardboard, is relatively new to the basin but is increasing in importance. Technological advances, and the ever-increasing necessity for maximum utilization of our natural resources, promise to open up new and increased uses for these timber by-products.

The California Oregon Power Company, serving electric power to the northern and eastern portions of the basin, and to additional areas in southern Oregon, has seven hydroelectric power installations on the Link and Klamath Rivers. These plants, located between Klamath Falls, Oregon, and Copco Lake and Fall Creek, California, have a combined installed capacity of about 133,000 kilowatts. In 1957 the Keno Power Plant, 750 kilowatts, was retired from service, and in 1958 the 80,000 kilowatt Big Bend Power Plant was completed. The Pacific Gas and Electric Company, serving most of the Trinity River drainage area, has one small hydroelectric power installation of 2,300 kilowatts on the Trinity River near Junction City.

Recreational facilities drawing many tourists annually into the area have been developed in the Klamath River Basin. Natural attractions such as Crater Lake, the Modoc Lava Beds, the Trinity Alps and Marble Mountain Primitive Areas, and the Coast Redwoods, have been enhanced by development of public picnic and camp grounds, roads, and trails. A program of management and protection of fish and wildlife in the basin has maintained the sports attraction of the area at a high level.

Based upon presently available statistics, the 1953 population of the Klamath River Basin has been estimated to be about 75,200 persons. The Oregon portion accounts for some 43,000 of these people, while California contains the remaining 32,200. Incorporated areas having present populations in excess of 3,000 persons are Klamath Falls, Oregon, with a population of about 16,200 and Yreka, California, with about 3,300. Smaller communities and rural dwellers account for the bulk of the population.

KLAMATH RIVER COMPACT

By 1953 it had become apparent to both Oregon and California that future demands for Klamath River water, both within the interstate basin and in other areas to which Klamath River water might be exported, would eventually force a determination of the proper distribution and use of Klamath River water to the mutual advantage of each state. Rather than leave this determination unsolved until the time when critical water needs might force a hasty, and possibly unsatisfactory settlement of the problem, the two states wisely agreed to face the issues which would inevitably rise, and through mutual agreement, determine how these interstate waters should be used for the fullest benefit of all parties concerned. To accomplish this purpose, bills were passed in each State Legislature in 1953, which established compact

commissions within each state. The function of these commissions was to cooperate in formulating and submitting to their respective legislatures an interstate compact relative to the distribution and use of the waters of the Klamath River. The consent of the Congress of the United States to the negotiation of an interstate compact was given by Public Law 316, 84th Congress, approved August 9, 1955.

The commissions of both states spent considerable time in becoming better acquainted with the water problems of the Klamath River Basin. Subsequently a compact, mutually agreeable to both commissions, was formulated and approved on November 17, 1956. This compact was ratified by the Legislatures of Oregon (Chapter 142, Oregon Laws 1957) and California (Water Code, Division 2, Part 6) on April 17, 1957. The compact was consented to by Act of Congress (71 Stat. 497) on August 30, 1957, and became effective on September 11, 1957.

The major purposes of this agreement, with respect to the water resources of the Klamath River Basin, are set forth in Article I of the compact:

"A. To facilitate and promote the orderly, integrated and comprehensive development, use, conservation and control thereof for various purposes, including, among others: the use of water for domestic purposes; the development of lands by irrigation and other means; the protection and enhancement of fish, wildlife, and recreational resources; the use of water for industrial purposes and hydroelectric power production; and the use and control of water for navigation and flood prevention.

"B. To further intergovernmental cooperation and comity with respect to these resources and programs for their use and development and to remove causes of present and future controversies by providing (1) for equitable distribution and use of water among the two States and the Federal Government, (2) for preferential rights to the use of water after the effective date of this Compact for the anticipated ultimate requirements for domestic and irrigation purposes in the Upper Klamath River Basin in Oregon and California, and (3) for prescribed relationships between beneficial uses of water as a practicable means of accomplishing such distribution and use."

Shackleford Creek, typical of perennial streams on west side of Scott Valley.

Department of Water Resources photograph

Salmon River

Eastman's Studio, Susanville, photograph

CHAPTER II
WATER SUPPLY

The principal sources of water supply for use within the Klamath River Basin are direct precipitation and surface runoff, although some ground water is pumped in portions of the basin. The known exports of water from, or imports of water to the basin are minor in quantity and not significant to the total water supply. The water supply of the Klamath River Basin is considered and evaluated in this chapter under the general headings of "Precipitation," "Runoff," "Imported and Exported Water," "Quality of Water," and "Ground Water."

The following terms are defined for use in connection with the discussion of water supply in this bulletin:

Annual—This refers to the 12-month period from January 1st of a given year through December 31st of the same year, sometimes termed the "calendar year."

Seasonal—This refers to any 12-month period other than the calendar year.

Precipitation Season—The 12-month period from July 1st of a given year through June 30th of the following year.

Runoff Season—The 12-month period from October 1st of a given year through September 30th of the following year.

Mean Period—A period chosen to represent mean conditions of water supply and climate. The 60-year period from 1894-95 through 1953-54, was assumed to represent a mean period of water supply in the Klamath River Basin.

Average Period—A period chosen during which the conditions of water supply and climate represent the mean period and during which reliable records are available. For purposes of this bulletin, the average period was chosen to be the 32-year period from 1920-21 through 1951-52.

Natural Runoff (Flow)—The flow of a stream as it would be if unaltered by upstream diversion, storage, import, export, or change in upstream consumptive use caused by development. Natural runoff is reconstructed from measured (actual) runoff by adjusting for the quantitative effect of alterations in the regimen of stream flow above the point where the flow is measured.

Present Impaired Flow—The flow of the stream as it would have occurred historically with the present upstream development being maintained in a constant condition throughout the selected period.

Ultimate Impaired Flow—The flow of a stream as it would have occurred historically if altered by probable ultimate conditions of upstream development.

Mean—The arithmetic average of a series of quantities relating to mean periods.

Average—The arithmetic average of a series of quantities relating to periods other than mean periods.

Safe Surface Water Yield—The maximum dependable rate at which surface water would be available throughout a chosen critically deficient water supply period, with a given condition of surface water supply development.

Safe Ground Water Yield—The maximum rate of net extraction of water from a ground water basin which, if continued over an indefinitely long period of years, would not result in the occurrence of certain undesirable conditions. Commonly, safe ground water yield is determined by one or more of the following criteria:

1. Mean seasonal extraction of water from the ground water basin does not exceed mean seasonal replenishment to the basin.
2. Water levels are not so lowered as to cause harmful impairment of the quality of the ground water by intrusion of water of undesirable quality, or by accumulation and concentration of degradants or pollutants.
3. Water levels are not so lowered as to imperil the economy of ground water users by excessive costs of pumping from the ground water basin, or by exclusion of users from a supply therefrom.

The 60-year period extending from 1894-95 through 1953-54 is considered, for purposes of this bulletin, to represent a mean period of surface water supply in the Klamath River Basin. Analysis of available precipitation records for stations within and adjacent to the basin indicated that the 50 years from 1899-1900 to 1948-49, inclusive, constitute a satisfactory period for estimating mean seasonal precipitation.

An average period for the determination of safe yield of proposed reservoirs was selected on the basis of available records, the occurrence of a critical series of dry years, and an approximate equality with the mean period water supply. The 32-year period from

1920-21 through 1951-52 was found to be satisfactory for this purpose in most respects. Stream flow during this period averaged about 85 per cent of the long time mean for streams of the upper basin. During this period a series of critically dry years occurred from 1928-29 through 1934-35, during which the available runoff averaged only about 63 per cent of the 60 year mean. Reservoirs of sufficient capacity for cyclic storage, when operated throughout the average period, were found to be at minimum stage in the fall of 1935. The 1923-24 season was also one of extremely deficient water supply, and reservoirs of limited seasonal carryover capacity reached a minimum stage during this season.

PRECIPITATION

The Klamath River Basin, covering an area of some 15,700 square miles, is subject to considerable variation in storm patterns within its boundaries. In general, the basin is in the path of storms which periodically sweep inland from the northern Pacific Ocean during winter months. The precipitation resulting from these storms is generally moderate, with fairly heavy rains occurring along the western portion of the basin and decreasing in intensity to the east. Depth of seasonal precipitation along the coastline averages about 40 inches, increasing to over 100 inches in the coastal mountains. Eastward the quantity of precipitation decreases to less than 10 inches in eastern Siskiyou County. Mean seasonal precipitation in the inland valleys, Scott, Shasta, and Butte, is about 20 inches, 15 inches, and 12 inches, respectively. Seasonal depth of precipitation on mountains adjacent to these valleys generally exceeds 40 inches and occurs both as rain and snow.

Precipitation Stations and Records

Seventy-seven precipitation stations in or adjacent to the Klamath River Basin have continuous records of 10 years duration or longer. The stations and map reference numbers are listed in Table 4. This table shows for each station the period of record and values of the mean, maximum, and minimum seasonal precipitation. Locations of the precipitation stations are shown on Plate 3, entitled "Lines of Equal Mean Seasonal Precipitation." Map reference numbers correspond to those utilized in State Water Resources Board Bulletin No. 1, "Water Resources of California," and Division of Water Resources reports on "Water Conditions in California." Reference numbers of stations not appearing in either of the above bulletins are prefaced with the initials "KRB." Mean seasonal depth of precipitation for stations with records covering a period of lesser length than the mean period was estimated by comparison with records of nearby stations having 50 years or more of record.

Precipitation stations with long records are located mainly in the valley and coastal areas of the basin, and thus are not indicative of amounts of precipitation which occurs principally as snow at the higher elevations. However, for many years snow surveys have been made to assist in predicting the runoff which will occur during the summer months. Data available from these snow surveys have been used to assist in preparing the isohyetal map of the basin shown on Plate 3.

Precipitation Characteristics

The Klamath River Basin is large in areal extent and includes a wide diversity of topography. Consequently, there is no single area wherein the rainfall is characteristic of the entire basin, and no single record that is representative of precipitation throughout the basin. Plate 3 shows that, in general, mean seasonal precipitation decreases from west to east, with the heaviest concentrations upon the coastal mountains, and the lightest rainfall on the inland plateau areas.

Data compiled from the records of four precipitation stations maintained for appreciable periods gives an indication of seasonal precipitation characteristics for representative geographical portions of the basin. These stations are Eureka, Weaverville, and Yreka in California, and Klamath Falls in Oregon. Seasonal rainfall at Eureka is a suitable index of general precipitation along the coastal belt, while rainfall at Weaverville is generally related to that occurring in the mountain valleys. The record at Yreka is indicative of that in the large valley areas, while general precipitation on the high plateau areas in the northern and eastern portion of the basin is similar to the record of rainfall at Klamath Falls. The recorded seasonal precipitation for the four stations is given in Table 5, and shown on Plate 4, entitled "Recorded Seasonal Precipitation at Selected Stations in the Klamath River Basin."

Precipitation in the Klamath River Basin varies considerably from month to month. About 75 per cent of the seasonal precipitation occurs during the 5-month period from November through March. The mean monthly distribution of precipitation at the four stations, Eureka, Weaverville, Yreka, and Klamath Falls, is presented in Table 6.

In plotting the lines of equal mean seasonal precipitation, or isohyets, shown on Plate 3, the 50-year mean seasonal depths of precipitation at stations with 10 years of record or longer, in or adjacent to the area, were first plotted on a map of the basin. Based upon these plottings, and considering local variations in topography and vegetation, as well as data obtained from snow survey measurements and short-period precipitation records, the isohyets were then drawn. The position of the isohyets was then adjusted and

TABLE 4

PRECIPITATION STATIONS WITH CONTINUOUS RECORDS OF 10 YEARS OR LONGER IN OR ADJACENT TO THE KLAMATH RIVER BASIN

Map reference number	Name of station	County	Location: Township	Location: Range	Location: Section and subdivision	Location: Base and meridian [1]	Elevation, in feet	Source of record [2]	Period of record	Seasonal depth of precipitation, in inches: Estimated mean, 1899-1900 to 1948-1949	Recorded maximum and minimum: Season	Recorded maximum and minimum: Inches
	OREGON											
KRB-1	Crescent	Klamath	25S	9E	6M	W.	4,452	USWB	1905-06 1944-45	19.68	1906-07 1905-06	24.96 14.98
KRB-2	Fremont	Lake	26S	13E	14E	W.	4,300	OAES	1910-11 1953-54	9.41	1951-52 1917-18	15.39 4.06
KRB-3	The Poplars	Lake	28S	15E	22D	W.	4,316	USWB	1943-44 1953-54	9.68	1952-53 1944-45	12.93 8.62
KRB-4	Chemult	Klamath	27S	8E	20J	W.	4,760	USWB	1937-38 1953-54	23.73	1942-43 1938-39	39.52 16.82
KRB-5	Silver Lake	Lake	28S	14E	22D	W.	4,496	USWB	1897-98 1923-24	10.27	1921-22 1923-24	12.88 4.61
KRB-6	Crater Lake National Park	Klamath	31S	6E	8J	W.	6,475	USWB	1931-32 1953-54	63.82	1950-51 1938-39	93.08 45.16
KRB-7	Sand Creek	Klamath	31S	7E	32A	W.	4,682	USWB	1930-31 1947-48	27.28	1942-43 1930-31	43.95 16.68
KRB-8	Prospect	Jackson	33S	3E	6E	W.	2,482	USWB	1908-09 1953-54	40.42	1942-43 1930-31	57.44 25.66
KRB-9	Fort Klamath	Klamath	33S	7½E	21G	W.	4,200	USA USWB	1875-76 1896-97	21.95	1896-97 1882-83	35.16 15.30
KRB-10	Paisley	Lake	33S	18E	24E	W.	4,371	USWB	1906-07 1953-54	9.02	1906-07 1930-31	14.51 4.97
KRB-11	Chiloquin	Klamath	34S	7E	35F	W.	4,200	USWB	1884-85 1953-54	17.02	1896-97 1928-29	35.16 9.18
KRB-12	Butte Falls 1 SE	Jackson	35S	2E	14C	W.	2,500	USWB	1910-11 1953-54	33.49	1918-19 1914-15	50.23 25.67
KRB-13	Valley Falls	Lake	36S	21E	18H	W.	4,326	USWB	1920-21 1953-54	12.32	1941-42 1932-33	17.36 6.84
KRB-14	Lake Creek	Jackson	37S	3E	8E	W.	2,000	USWB	1918-19 1953-54	27.68	1947-48 1919-20	29.08 16.07
KRB-15	Medford Airport	Jackson	37S	1W	7F	W.	1,314	USWB	1911-12 1953-54	18.34	1937-38 1925-26	25.31 10.90
*KRB-16	Fish Lake	Jackson	27S	4E	9J	W.	4,687	USWB	1918-19 1953-54	44.44	1942-43 1929-30	66.54 27.74
KRB-17	Round Grove	Jackson	37S	15E	25H	W.	4,888	USWB	1920-21 1953-54	16.14	1941-42 1923-24	21.63 9.94
KRB-18	Jacksonville	Jackson	38S	2W	6C	W.	1,610	USWB	1889-90 1944-45	25.14	1903-04 1923-24	41.68 13.16
KRB-19	Dairy 3NE-Yonna	Klamath	38S	10E	24A	W.	4,150	USWB	1908-09 1953-54	13.44	1939-40 1917-18	19.95 8.02
KRB-20	Talent	Jackson	38S	1W	13E	W.	1,550	USWB	1920-21 1953-54	18.80	1937-38 1925-26	25.48 11.57
KRB-21	Klamath Falls	Klamath	38S	9E	32J	W.	4,190	USWB	1884-85 1953-54	12.93	1885-86 1917-18	19.82 7.53
KRB-22	Ashland	Jackson	38S	1E	32J	W.	1,750	USWB	1879-80 1953-54	20.22	1926-27 1882-83	29.77 11.56
KRB-23	Gerber Dam	Klamath	39S	14E	12M	W.	4,800	USWB	1926-27 1953-54	17.11	1937-38 1928-29	24.14 9.85
*KRB-24	Lakeview	Lake	39S	20E	15M	W.	4,756	USWB	1884-85 1953-54	13.49	1906-07 1930-31	22.82 6.91

TABLE 4—Continued

PRECIPITATION STATIONS WITH CONTINUOUS RECORDS OF 10 YEARS OR LONGER IN OR ADJACENT TO THE KLAMATH RIVER BASIN

Map reference number	Name of station	County	Location				Elevation, in feet	Source of record [2]	Period of record	Seasonal depth of precipitation, in inches		
			Township	Range	Section and subdivision	Base and meridian [1]				Estimated mean, 1899-1900 to 1948-1949	Recorded maximum and minimum	
											Season	Inches
	OREGON—Continued											
KRB-25	Keno	Klamath	39S	7E	36J	W	4,040	USWB	1928-29 1953-54	17.54	1937-38 1930-31	25.95 9.02
KRB-26	Siskiyou Summit	Jackson	40S	2E	32A	W.	4,480	USWB	1889-90 1947-48	29.82	1920-21 1890-91	54.41 12.13
KRB-27	Merrill 2NW	Klamath	40S	10E	34G	W.	4,085	USWB	1906-07 1925-26	10.87	1911-12 1909-10	18.14 5.84
KRB-28	Malin	Klamath	41S	12E	16E	W.	4,050	USWB	1925-26 1945-46	11.49	1942-43 1930-31	17.15 5.58
	CALIFORNIA											
1-002	Elk Valley	Del Norte	19N	4E	35D	H.	1,171	USWB	1938-39 1953-54	90.30	1950-51 1938-39	108.40 54.63
KRB-29	Hilt Slash Disposal	Siskiyou	48N	7W	21D	M.D.	2,900	USWB	1939-40 1953-54	21.36	1952-53 1943-44	29.26 14.99
KRB-30	Copco	Siskiyou	48N	4W	29L	M.D.	2,700	OAES	1928-29 1953-54	17.58	1937-38 1938-39	23.58 8.70
1-3	Tulelake	Siskiyou	48N	4E	26R	M.D.	4,036	USWB	1932-33 1953-54	8.80	1939-40 1932-33	14.18 4.78
KRB-31	Clear Lake Dam	Modoc	47N	8E	9D	M.D.	4,570	USBR	1912-13 1953-54	12.99	1944-45 1938-39	18.23 6.64
1-2	Hornbrook	Siskiyou	47N	6W	29C	M.D.	2,154	USWB	1888-89 1917-18	13.07	1889-90 1912-13	25.65 6.85
1-4	Steele Swamp	Modoc	47N	9E	33Q	M.D.	5,000	USWB	1923-24 1948-49	12.83	1944-45 1938-39	18.23 6.64
*6-1	Fort Bidwell	Modoc	46N	16E	9N	M.D.	4,735	USWB	1866-67 1953-54	15.48	1866-67 1932-33	35.70 7.69
1-6	Happy Camp Ranger Station	Siskiyou	16N	7W	11M	H.	1,088	USWB	1915-16 1953-54	52.40	1937-38 1923-24	85.60 24.71
KRB-32	Mount Hebron Ranger Station	Siskiyou	45N	1W	7C	M.D.	4,250	USWB	1942-43 1953-54	10.44	1944-45 1949-50	12.80 7.05
*1-1	Crescent City (near)	Del Norte	17N	1E	30J	H.	125	USWB	1913-14 1953-54	81.28	1920-21 1923-24	107.77 34.52
1-7	Scott Bar	Siskiyou	45N	10W	21K	M.D.	1,800	USWB	1922-23 1934-35	29.64	1926-27 1923-24	49.18 15.04
1-9	Yreka	Siskiyou	45N	7W	27K	M.D.	2,625	USWB USFS	1871-72 1953-54	18.12	1903-04 1923-24	31.29 7.89
1-10	Montague	Siskiyou	45N	6W	22M	M.D.	2,517	USWB	1888-89 1946-47	11.89	1889-90 1897-98	24.19 4.14
1-8	Walla Walla Creek	Siskiyou	43N	9W	11D	M.D.	2,570	USWB	1860-61 1891-92	32.20	1889-90 1874-75	49.97 12.72
1-11	Grenada	Siskiyou	44N	6W	21H	M.D.	2,560	DWR	1908-09 1937-38	12.22	1913-14 1917-18	20.07 6.40
*6-2	Lake City	Modoc	44N	15E	36N	M.D.	4,613	USWB	1929-30 1953-54	20.43	1951-52 1930-31	41.03 11.68
KRB-33	Fort Jones Ranger Station	Siskiyou	44N	9W	35P	M.D.	2,747	USWB USFS	1936-37 1953-54	20.79	1937-38 1943-44	29.85 13.73
*5-1	Alturas	Modoc	42N	12E	13C	M.D.	4,346	USWB USFS	1904-05 1953-54	12.94	1951-52 1930-31	21.09 6.49

TABLE 4—Continued

PRECIPITATION STATIONS WITH CONTINUOUS RECORDS OF 10 YEARS OR LONGER IN OR ADJACENT TO THE KLAMATH RIVER BASIN

Map reference number	Name of station	County	Location: Township	Location: Range	Location: Section and subdivision	Location: Base and meridian [1]	Elevation, in feet	Source of record [2]	Period of record	Seasonal depth of precipitation in inches: Estimated mean, 1899-1900 to 1948-1949	Recorded maximum and minimum: Season	Recorded maximum and minimum: Inches
	CALIFORNIA—Continued											
1-12	Edgewood	Siskiyou	42N	5W	21P	M.D.	2,963	DWR	1888-89 1946-47	18.22	1940-41 1938-39	39.12 9.15
1-039	Etna	Siskiyou	42N	9W	29B	M.D.	2,950	Private USFS	1935-36 1953-54	25.12	1937-38 1943-44	41.26 14.90
5-2	Mount Shasta Weather Bureau	Siskiyou	40N	4W	16C	M.D.	3,550	USWB	1888-89 1953-54	34.85	1889-90 1898-99	73.47 15.97
KRB-34	Callahan Ranger Station	Siskiyou	40N	8W	21E	M.D.	3,200	USWB USFS	1944-45 1953-54	22.31	1952-53 1949-50	21.16 13.22
KRB-35	Sawyers Bar Ranger Station	Siskiyou	40N	11W	29K	M.D.	2,175	USWB USFS	1933-34 1953-54	43.54	1951-52 1943-44	61.39 28.28
1-13	Orleans	Humboldt	11N	6E	31J	H.	423	USWB	1903-04 1953-54	50.00	1903-04 1923-24	81.93 22.78
5-4	McCloud	Siskiyou	39N	3W	1R	M.D.	3,270	USWB	1911-12 1953-54	49.35	1940-41 1923-24	87.30 16.27
5-3	Dunsmuir	Siskiyou	39N	4W	25A	M.D.	2,285	USWB	1889-90 1953-54	51.87	1889-90 1890-91	119.02 25.74
*5-8	Bieber	Lassen	38N	7E	23K	M.D.	4,169	DWR	1930-31 1953-54	16.84	1937-38 1938-39	28.32 9.10
1-009	Hoopa-Fort Gaston	Humboldt	8N	4E	26F	H.	359	USWB	1861-62 1953-54	51.53	1865-66 1872-73	128.97 31.09
1-14	Trinidad Head	Humboldt	8N	1W	26E	H.	198	USGS	1919-20 1938-39	43.52	1920-21 1930-31	58.50 23.33
*5-6	Big Bend	Shasta	37N	1W	36K	M.D.	2,000	Private	1927-28 1937-38	66.48	1937-38 1930-31	101.39 36.14
*5-7	Fall River Mills Intake	Shasta	37N	4E	26H	M.D.	3,340	USWB	1924-25 1953-54	18.64	1937-38 1938-39	30.08 10.42
5-10	Delta	Shasta	36N	5W	35R	M.D.	1,138	USWB	1882-83 1915-16	61.75	1889-90 1887-88	124.47 25.50
1-16	China Flat	Trinity	6N	5E	26F	H.	650	USWB	1909-10 1953-54	48.06	1926-27 1923-24	71.32 22.55
*5-11	Montgomery Creek	Shasta	35N	1W	35A	M.D.	2,180	USWB	1908-09 1918-19	54.22	1908-09 1916-17	73.35 36.90
1-18	Eureka	Humboldt	5N	1W	15L	H.	62	USWB	1878-79 1953-54	37.51	1889-90 1923-24	74.10 20.67
KRB-36	Big Bar Ranger Station	Trinity	33N	12W	5C	M.D.	1,248	USWB	1914-15 1953-54	37.66	1950-51 1919-20	51.03 21.26
1-19	Weaverville	Trinity	33N	9W	7E	M.D.	2,050	USWB	1871-72 1953-54	36.21	1889-90 1923-24	67.04 17.92
5-13	Kennett	Shasta	33N	5W	11L	M.D.	661	USWB	1907-08 1941-42	64.98	1940-41 1923-24	112.76 19.47
5-0180	Shasta Dam	Shasta	33N	5W	15K	M.D.	1,078	USWB	1943-44 1953-54	53.17	1951-52 1949-50	70.24 32.82
5-16	Shasta	Shasta	32N	6W	25H	M.D.	1,148	USWB	1895-96 1911-12	46.09	1903-04 1897-98	78.60 25.37
5-17	Redding	Shasta	32N	5W	35P	M.D.	569	USWB	1875-76 1953-54	36.76	1940-41 1897-98	68.87 15.66

TABLE 4—Continued

PRECIPITATION STATIONS WITH CONTINUOUS RECORDS OF 10 YEARS OR LONGER IN OR ADJACENT TO THE KLAMATH RIVER BASIN

Map reference number	Name of station	County	Location: Township	Location: Range	Location: Section and subdivision	Location: Base and meridian [1]	Elevation, in feet	Source of record [2]	Period of record	Seasonal depth of precipitation in inches: Estimated mean, 1899-1900 to 1948-1949	Recorded maximum and minimum: Season	Recorded maximum and minimum: Inches
	CALIFORNIA—Continued											
1-21	Hayfork Ranger Station	Trinity	31N	12W	12R	M.D.	2,340	USWB	1915-16 1953-54	31.94	1920-21 1923-24	45.30 13.53
*1-20	Rohnerville	Humboldt	2N	1W	13L	H.	75	USWB	1901-02 1919-20	43.52	1904-05 1917-18	61.49 27.48
*1-22	Scotia	Humboldt	1N	1E	8E	H.	163	USWB	1926-27 1953-54	46.40	1937-38 1930-31	77.02 25.48
KRB-37	Mad River Ranger Station	Trinity	1N	6E	20E	H.	2,700	USWB	1944-45 1953-54	60.87	1952-53 1946-47	72.14 44.42
KRB-38	Forest Glen	Trinity	1S	7E	13B	H.	2,340	USWB	1930-31 1953-54	67.09	1937-38 1930-31	98.59 35.57
KRB-39	Harrison Gulch Ranger Station	Shasta	29N	10W	15H	M.D.	2,170	USWB	1944-45 1953-54	36.82	1951-52 1949-50	47.22 23.55
1-23	Ruth	Trinity	1S	7E	14G	H.	2,750	USWB	1912-13 1937-38	57.33	1937-38 1923-24	95.17 23.38

* Station locations not shown on Plate 4.

[1] Base and Meridian:
W—Williamette
H—Humboldt
MD—Mount Diablo

[2] Source of record:
COPCO—The California Oregon Power Company
DWR—Division of Water Resources
OAES—Oregon Agricultural Experiment Station
USA—United States Army
USBR—United States Bureau of Reclamation
USGS—United States Geological Survey
USFS—United States Forest Service
USWB—United States Weather Bureau

checked by making a hydrologic analysis of selected drainage basins above points of measured and estimated stream flow. The total volume of precipitation on a selected watershed was determined from the isohyetal map. Next, the estimated runoff was computed by subtracting from the volume of precipitation estimates of evaporation, consumptive use, and other losses. This estimated runoff was then compared with the measured mean seasonal runoff. Where the comparison was not favorable, adjustments were made in the position of the isohyets in order that the runoff, as computed from precipitation, would agree with measured mean seasonal runoff.

RUNOFF

The watersheds of the Cascade and the Coast Ranges within the Klamath River Basin produce nearly one-fifth of California's natural runoff. A substantial portion of this water resource is unregulated and undeveloped for use. It comprises a potential source of water to meet future requirements, not only within the basin, but in water-deficient areas in other parts of California.

Stream Gaging Stations and Records

Adequate records of runoff are available only on the major streams of the Klamath River Basin. These records were utilized as the principal basis for estimates of water supply. Runoff data on the smaller streams tributary to the agricultural areas were generally limited to records maintained during the summer months by watermasters, and short-period records and miscellaneous measurements made by other agencies. Extensive stream flow and diversion records have been maintained by the United States Bureau of Reclamation in the Klamath Project area since 1904.

Stream gaging stations with records of particular value in the determination of the hydrography of the Klamath River Basin, together with their map reference numbers, drainage areas above stations where significant, and periods and sources of records are listed in Table 7. Most of the records listed in Table 7 have been published in the Water-Supply Papers of the United States Geological Survey. The locations of these stations are shown on Plate 3. The plate reference numbers for most stations listed correspond to

TABLE 5

RECORDED SEASONAL PRECIPITATION AT SELECTED STATIONS IN THE KLAMATH RIVER BASIN

(In inches of depth)

Season	Eureka	Weaverville	Yreka	Klamath Falls
1871-1872		54.57	14.25*	
73		21.06	12.04	
74		40.24	12.77	
1874-1875		21.72	10.20	
76		51.13	22.04	
77		32.24	14.02	
78		60.70	18.73	
79	26.83	38.21	13.32	
1879-1880	38.40	37.00	17.57	
81	31.91	49.72	20.48	
82	41.24	28.93	13.08	
83	32.54	31.32	12.16	
84	25.05	38.09	16.20	
1884-1885	21.21	29.41	19.68	16.73*
86	43.73	44.96	18.95	19.83*
87	44.17	31.35	19.03	13.11
88	34.17	37.54	15.70	13.14
89	34.14	29.74	10.42	10.52
1889-1890	74.10	67.04	30.42*	
91	35.41	30.18	12.92*	
92	38.14	36.51	14.12*	
93	49.15	46.16	16.53	
94	55.20		30.50	
1894-1895	45.97		19.75	
96	52.45		23.28	
97	51.10		20.84	
98	35.12		13.05	
99	35.72		12.41	14.77
1899-1900	51.73		18.11	
01	47.58		23.55	
02	51.96		19.34	10.78
03	51.73		16.12*	
04	65.21		31.29*	
1904-1905	32.74		20.28	10.31*
06	39.04		22.10	13.47
07	50.54		25.54*	14.48*
08	35.99			11.42
09	42.96			13.66
1909-1910	40.36			14.65
11	32.09			14.89
12	38.65			14.53
13	36.03	31.55		17.17
14	37.32	46.02		15.48
1914-1915	42.42	43.87		10.34
16	39.99	34.60	17.29	11.44
17	31.36	26.17	12.67	10.74
18	24.34	22.46	11.08	7.53
19	39.80	38.58	19.63	11.61
1919-1920	23.95	20.52	9.25	7.95
21	48.81	50.41	21.96	14.79
22	34.76	25.48	14.61	11.93
23	25.18	28.17	13.80	12.74
24	20.67	17.92	7.89	8.19
1924-1925	41.50	46.62	26.25	17.44
26	26.78	28.08	11.83	8.69
27	50.58	51.54	27.38	18.83
28	30.71	32.49	15.39	13.03
29	29.40	20.21	11.33	8.49
1929-1930	23.53	28.04	14.88	10.76
31	21.29	22.85	13.46	8.42
32	36.62	27.68	15.32	12.33
33	34.87	27.55	13.75	9.61
34	22.66	25.65	11.07	8.82
1934-1935	39.81	32.52	14.44	11.67
36	34.55	39.41	19.81	16.51
37	30.25	26.40	13.85	12.24
38	56.56	41.40	26.50	17.55
39	30.88	26.15	10.16	8.55
1939-1940	40.56	45.57	22.29	18.13
41	48.08	52.24	20.28	15.87
42	42.26	41.25	23.63	17.17
43	41.04	38.03	21.85	17.83*
44	27.85	23.96	10.89	10.38
1944-1945	43.22	32.04	15.68	14.34
46	40.04	35.27	17.37	14.14
47	21.39	28.47	11.61	11.60
48	42.25	34.14	18.31	14.64
49	33.65	31.80	15.30	16.19
1949-1950	40.80	31.27	14.21	11.91
51	46.33	46.88	21.60	15.60
52	47.40	49.02	24.42	17.52
53	47.63	48.92*	24.23	16.46
Mean for 50-year period from 1899-1900 through 1948-1949	37.51	36.21	18.12	12.94

TABLE 5—Continued

RECORDED SEASONAL PRECIPITATION AT SELECTED STATIONS IN THE KLAMATH RIVER BASIN

(In inches of depth)

* Partially estimated.

those used in State Water Resources Board Bulletin No. 1, "Water Resources of California." New map reference numbers were assigned to those stream gaging stations within the Klamath River Basin in Oregon, and to those stations installed in the California portion of the basin by other agencies since the publication of Bulletin No. 1.

During the present investigation, 20 stream gaging stations were established at strategic locations within the basin to provide data required for more precise knowledge of runoff. These stations are listed in Table 8. The location of these gaging stations is also shown on Plate 3. Continuation of certain of these stations will provide invaluable data for future planning and operation of water development works.

Runoff Characteristics

Runoff from streams in the Klamath River system varies between wide limits, both from season to season, and within the season. The flow of the Trinity River at Lewiston is indicative of this variation. Seasonal runoff at that station, recorded continuously since 1911, has ranged between 2,547,000 acre-feet in 1940-41, and 266,000 acre-feet in 1923-24, while the 60-year mean has been about 1,288,000 acre-feet. At the same station, the instantaneous discharge has ranged from an estimated maximum of 71,600 second-feet on December 22, 1955, to about 23 second-feet on July 20, 1924. Typical data on the discharge of this and other selected stations in the Klamath River Basin are presented in Table 9.

Both rainfall and snowmelt runoff supply the streams of the Klamath River Basin. Extreme variations in the topography, vegetative cover, and geologic

TABLE 6

MONTHLY DISTRIBUTION OF MEAN SEASONAL PRECIPITATION AT SELECTED STATIONS IN THE KLAMATH RIVER BASIN

Month	Eureka		Weaverville		Yreka		Klamath Falls	
	In inches of depth	In percent of seasonal total	In inches of depth	In percent of seasonal total	In inches of depth	In percent of seasonal total	In inches of depth	In percent of seasonal total
January	6.33	16.9	6.36	17.6	2.72	15.1	1.99	15.3
February	6.03	16.1	5.93	16.4	2.65	14.6	1.51	11.7
March	4.99	13.3	3.89	10.7	1.78	9.8	1.07	8.3
April	2.87	7.6	2.70	7.5	1.04	5.7	0.83	6.4
May	1.72	4.6	1.38	3.8	0.93	5.1	0.91	7.0
June	0.66	1.8	0.91	2.5	0.67	3.7	0.78	6.0
July	0.13	0.3	0.15	0.4	0.36	2.0	0.31	2.4
August	0.16	0.4	0.14	0.4	0.31	1.7	0.28	2.2
September	0.81	2.2	0.70	1.9	0.55	3.0	0.54	4.2
October	2.51	6.7	2.26	6.2	1.27	7.0	1.02	7.9
November	5.29	14.1	5.04	13.9	2.72	15.1	1.84	14.2
December	6.01	16.0	6.75	18.7	3.12	17.2	1.86	14.4
TOTALS	37.51	100.0	36.21	100.0	18.12	100.0	12.94	100.0

structure of the various watersheds affect the pattern and regimen of runoff. In the extreme northern portions of the basin the Williamson and Wood Rivers, two of the principal streams, draining 3,800 square miles of high plateau watershed, discharge directly into Upper Klamath Lake. Although precipitation occurs principally in the winter months, the resulting water supply percolates into the volcanic substructure of the area, moves through the permeable pumice deposits of the Klamath Marsh, and finally is discharged by the two rivers in almost constant monthly amounts. The Sprague River drains the eastern portion of the watershed area and maintains a high base flow, characteristic of volcanic terrain, yet this stream is subject to high runoff in the spring months.

The Klamath River heads in Upper Klamath Lake, controlled at its outlet by Link River Dam. Under natural conditions this lake, and the now reclaimed area of Lower Klamath Lake, had considerable regulatory effect on the Klamath River. During flood stages the natural flows would leave the stream channels, flood the adjoining flat lands and lake bottom, fill the sump areas, and later return at reduced rates of flow to the main channel. Upper Klamath Lake continues to regulate high flows in the river, but reclamation of the Lower Klamath Lake area now prevents flood waters from entering.

To the east and south of Lower Klamath Lake are the Lost River watershed, the lava bed areas tributary to Tule Lake Sump and Lower Klamath Lake, and the closed basin of Butte Valley. Under natural conditions this extensive area of approximately 3,000 square miles contributed no surface flow to the Klamath River. Under present conditions the drainage water from irrigation and flood flows return to the Klamath River. Rainfall on the Lost River Basin averages a depth of less than 12 inches per season, and most of that not retained within the soil mantle or consumptively used percolates into the lava substructure.

Surface runoff to Shasta Valley occurs in the tributary streams of Dale, Eddy, Parks, and Willow Creeks, all of which head in the nonvolcanic area southwest of the valley. The northern slope of Mt. Shasta on the southeasterly watershed of Shasta Valley contributes no surface runoff; all precipitation and snowmelt percolates into the lavas and appears on the surface in springs or discharges directly from the ground water into Shasta River. The only significant surface runoff from the Cascade Range along the eastern edge of Shasta Valley occurs in the Little Shasta River. Small intermittent creeks drain the area of relatively light precipitation along the western edge of Shasta Valley.

In the Scott, Salmon, Trinity, and other tributaries of the lower Klamath River, the pattern of runoff is a function of the rain and snow storms. These streams are characterized by low flows in the summer and fall months, and by high flows during the early winter rainstorms and during the snowmelt periods of April, May, and June.

Estimated average monthly distribution of natural runoff at selected stations in the Klamath River Basin is presented in Table 10.

Quantity of Runoff

In general, estimates of the mean seasonal natural runoff of the Klamath River and its four principal tributaries, the Shasta, Scott, Salmon, and Trinity Rivers, were variously determined from available stream flow records, from correlations with the runoff of nearby streams having continuous records over long periods, from correlations with rainfall records, and from data obtained in connection with land use surveys. In these estimates of natural flow, Butte Valley

TABLE 7

STREAM GAGING STATIONS IN THE KLAMATH RIVER BASIN

Map reference number	Stream	Station	Drainage area, in sq. miles	Periods of record	Sources* of record
1-1	Link River	at Klamath Falls	3,810	1904-57	USGS
1-2	Lost River	at Clear Lake	550	1904-09	USGS
1-3	Antelope Creek	near Macdoel	30	1921-22	USGS
1-4	Butte Creek	near Macdoel	178	1921-22 1951-57	USGS
1-5	Shovel Creek (Bear Creek)	near Macdoel	20	1921-22	USGS
1-6	Klamath River	at Keno	3,920	1904-57	USGS
1-7	Fall Creek	at Copco	20	1928-57	USGS
1-8	Klamath River	below Fall Creek near Copco	4,370	1928-57	USGS
1-8a	Klamath River	near Copco	4,350	1923-28	USGS
1-9	Jenny Creek	near Copco		1922-24	USGS
1-10	Shasta River	above Edson-Foulke Ditch		1934-57	DWRW
1-11	Beaughan Creek	below Long Bell		1922-57	DWRW
1-12	Shasta River	at Edgewood Bridge	120	1936-57	DWRW
1-13	Carrick Springs	near Weed		1934-57	DWRW
1-15	Parks Creek	at Robertson Weir		1939-57	DWRW
1-16	Big Springs	at head		1934-57	DWRW
1-19	Cleland Springs	at head		1928-57	DWRW
1-20	Shasta River	near Montague	670	1911-57	USGS, DWRW
1-21	Shasta River	near Yreka	796	1933-57	USGS
1-22	Scott River, East Fork	near Callahan	58	1910-13	USGS
1-23	Scott River, East Fork	at Callahan	114	1913-21 1952-57	USGS
1-24	Scott River	at Callahan	168	1911-21	USGS
1-25	Scott River	near Fort Jones	662	1941-57	USGS
1-26	Scott River	near Scott Bar	815	1911-13	USGS
1-27	Klamath River	near Seiad Valley	6,980	1912-57	USGS
1-28	Indian Creek	near Happy Camp	120	1911-21	USGS
1-30	Klamath River	near Happy Camp	7,070	1911-12	USGS
1-31	Salmon River	at Somesbar	746	1911-57	USGS
1-32	Klamath River	at Somesbar	8,480	1927-57	USGS
1-33	Coffee Creek	at Coffee	102	1910-14	USGS
1-34	Swift Creek	near Trinity Center	35	1910-14	USGS
1-35	Trinity River	near Trinity Center	298	1910-13	USGS
1-36	Trinity River, East Fork	Near Trinity Center	109	1910-14	USGS
1-37	Trinity River	at Lewiston	727	1911-57	USGS
1-38	Trinity River	near Douglas City	1,017	1944-51	USGS
1-39	Trinity River, North Fork	at Helena	152	1911-13	USGS
1-40	Trinity River	near Burnt Ranch	1,438	1931-40 1956-57	USGS
1-41	New River	near Denny	179	1927-28	USGS
1-42	Trinity River	near China Flat	1,733	1911-13	USGS
1-43	Trinity River, South Fork	near China Flat	909	1911-13	USGS
1-44	Trinity River	at Hoopa	2,846	1911-18	USGS
	Trinity River	near Hoopa	2,846	1931-57	USGS
1-45	Klamath River	near Requa	12,200	1910-26	USGS
	Klamath River	near Klamath	12,100	1950-57	USGS
KRB-1	Miller Creek	near Crescent		1911-14	USGS
KRB-2	Williamson River	near Silver Lake		1917-21	USGS
KRB-3	Scott Creek	near Fort Klamath		1917-20	USGS
KRB-4	Sand Creek	near Fort Klamath		1912-22	USGS
KRB-5	Long Creek	near Silver Lake		1918-29	USGS
KRB-6	Sycan River	near Silver Lake		1905-22	USGS
KRB-7	Annie (Anna) Creek	near Fort Klamath		1922-27	USGS
KRB-8	Wood River	at Fort Klamath		1911-36	USGS
KRB-9	Williamson River	above Spring Creek near Klamath Agency (Chiloquin)	1,330	1912-25	USGS
KRB-10	Sprague River	at McCready Ranch, near Chiloquin	1,580	1920-31	USGS
KRB-11	Sprague River	near Chiloquin	1,580	1931-57	USGS
KRB-12	Williamson River	at Chiloquin	1,400	1911-17	USGS
KRB-13	Sprague River	at Chiloquin	1,600	1911-25	USGS
KRB-14	Williamson River	below Sprague River near Chiloquin	3,000	1917-57	USGS
KRB-15	Sycan River	near Beatty (near Yainax)	530	1911-25	USGS
KRB-16	Fivemile Creek	near Bly		1917-21	USGS
KRB-17	Sprague River, North Fork	near Bly		1917-26	USGS
KRB-18	Fourmile Lake Reservoir on Fourmile Creek	near Recreation (Odessa)	15	1923-57	USGS
KRB-19	Sprague River	near (at) Yainax	1,270	1904-05	USGS
KRB-20	Whiskey Creek	near Beatty		1917-19	USGS
KRB-21	Sprague River	near Beatty (above Yainax)	513	1918-57	USGS
KRB-22	Cascade Canal	near Fish Lake		1923-57	OSE, USGS
KRB-23	Sprague River, South Fork	(Head of Sprague River) near Bly		1925-26	USGS
KRB-24	Anderson Creek	near Klamath Falls		1946-49	OSE
KRB-25	Upper Klamath Lake	near Klamath Falls	3,810	1904-07	USGS, USBR, COPCO, USWB
KRB-26	"A" Canal	at Klamath Falls		1910-57	USGS, USBR
KRB-27	Beaver Creek	near Lilyglen (Ashland)	30	1916-53	OSE, USGS
KRB-28	Keno Canal	at Klamath Falls		1923-52	COPCO
KRB-29	Miller Creek	at Gerber Dam	220	1904-10	USGS
KRB-30	Lost River	at Olene	1,290	1907-12	USGS
KRB-31	Lost River	above Olene		1915-17	USGS
KRB-32	Keene Creek	at Hyatt Prairie Reservoir, near Ashland	11	1917-57	USGS
KRB-33	Keene Creek Canal	near Ashland		1923-49	USGS
KRB-34	Klamath River	at Spencer Bridge near Keno	4,045	1913-31	USGS
KRB-35	Miller Hill Pumping Plant			1948-57	USBR
KRB-36	Diversion from Klamath River to Lost River	above Olene		1931-57	USGS, USBR
KRB-37	Lost River	at diversion dam near Olene		1904-20	USGS, USBR
KRB-38	Lost River Diversion Canal	near Olene (Klamath Falls)		1912-57	USGS, USBR
KRB-39	Lost River	at Wilson Bridge near Olene		1912-20	USGS
KRB-40	Keene Creek	near Lincoln		1940-48	OSE, USGS
KRB-41	Little Beaver Creek	at Pinehurst		1943-48	OSE, USGS
KRB-42	Miller Creek	near Lorella	270	1904-20	USGS
KRB-43	Diversions from Klamath River	at Ady		1926-57	USBR
KRB-44	Ady Pump to Klamath River	at Ady		1943-57	USBR
KRB-45	Lost River	near Merrill	1,420	1904-09	USGS
KRB-46	Sheepy Creek	near Dorris		1953-54	USBR, DWR
KRB-47	Hot Creek	near Dorris		1953-54	USBR, DWR
KRB-48	Cottonwood Creek	near Dorris		1953-54	USBR, DWR
KRB-50	Shovel Creek	at Upper Crossing	16	1951-54	USBR, DWR
KRB-51	Ikes Creek	near Macdoel	4	1953-54	USBR, DWR
KRB-52	Harris Creek	near Macdoel	2	1953-54	USBR, DWR
KRB-53	Muskgrave Creek	near Macdoel	3	1953-54	USBR, DWR
KRB-54	Willow Creek	near Dorris		1953-54	USBR, DWR
KRB-55	Prather Creek	near Mt. Hebron	4	1951-54	USBR, DWR
KRB-62	Antelope Creek	near Tennant	19	1952-57	USGS
KRB-66	Whitney Creek	at Highway U.S. 97		1952-53	DWR
KRB-74	Trinity River, South Fork	near Salyer	899	1950-57	USGS
KRB-75	Hayfork Creek	near Hyampom	379	1953-57	USGS

Stations for which the period of record extends to 1957 were active and under continuous operation at the time of publication of this bulletin.

* USGS—United States Geological Survey
DWR—Division of Water Resources
DWRW—Division of Water Resources Watermaster
OSE—Oregon State Engineer
COPCO—The California Oregon Power Company
USBR—United States Bureau of Reclamation
USWB—United States Weather Bureau

TABLE 8

STREAM GAGING STATIONS ESTABLISHED DURING THE KLAMATH RIVER BASIN INVESTIGATION

Map reference number	Stream and general location of gaging station		Drainage area, in square miles	Date established
1-14	*Parks Creek[a]	below Duke North Ditch	19	11- 6-52 to 9-27-54
1-18	*Little Shasta River	above Harp Ditch	46	10-16-52 to 10-16-56
KRB-49	Bogus Creek	near Bogus School	27	10-10-53 to 10-26-54
KRB-56	Yreka Creek	at Yreka	20	3-27-53 to 12-10-54
KRB-57	Greenhorn Creek	at Yreka	12	5-11-53 to 7- 8-54
KRB-58	Indian Creek	near Fort Jones	14	2-20-53 to 11-10-54
KRB-59	Moffett Creek	at Yreka-Fort Jones Highway	69	10-10-52
KRB-60	#Canyon Creek	near Kelsey Creek Guard Station	25	10-11-50
KRB-61	#Shackleford Creek	near Mugginsville	18	10-11-50
KRB-63	Kidder Creek	at Greenview	24	1-28-53 to 10-28-54
KRB-64	Willow Creek	near Gazelle	12	2-16-53
KRB-65	Patterson Creek	near Etna	12	1-28-53 to 10-28-54
KRB-67	Parks Creek Diversion to Shasta River	near Edgewood	--	10-29-52 to 6-22-54
KRB-68	Edson-Foulke (Yreka) Ditch	north of Parks Creek	--	5-15-53 to 9-26-54
KRB-69	#Etna Creek	near Etna	20	9-26-50
KRB-70	French Creek	above Long Bell Lumber Mill	29	4-28-53 to 10-18-54
KRB-71	Scott River, East Fork	above Grouse Creek	57	12-14-53 to 4- 7-55
KRB-72	Sugar Creek	near Callahan	12	1-26-53 to 1954
KRB-73	Scott River, South Fork	near Callahan	41	10-10-52 to 1958

* Earlier records of flow during the irrigation season are available for stations at or near these locations.
# Stations installed by United States Forest Service in cooperation with the Division of Water Resources. Ratings and computations made by Division personnel in conjunction with the Klamath River Basin Investigation.
[a] Station formerly known as Parks Creek above Duke North Ditch.

TABLE 9

RECORDED DISCHARGE OF PRINCIPAL STREAMS AT SELECTED STATIONS IN THE KLAMATH RIVER BASIN

Station	Period of record	Maximum and minimum seasonal discharge		Maximum and minimum instantaneous discharge prior to December, 1955		Maximum discharge during flood of December, 1955 in second-feet
		Season	Acre-feet	Date	Second-feet	
Klamath River at Keno	1904-54	1913-14 1930-31	1,970,000 395,000	5-10-04 8-4-34	9,250 35	----
Shasta River near Yreka	1933-41 1944-54	1937-38 1933-34	288,000 78,000	2-29-40 8-13-39	2,440 3.4	4,870
Scott River near Fort Jones	1941-54	1951-52 1943-44	740,000 168,000	2-2-52 10-3-47	8,320 36	38,500
Salmon River at Somesbar	1911-15 1927-54	1937-38 1930-31	2,234,000 473,000	12-28-45 8-25-31	33,000 70	----
Trinity River at Lewiston	1911-54	1940-41 1923-24	2,547,000 266,000	2-28-40 7-20-24	40,300 23	71,600
Trinity River near Hoopa	1911-14 1916-18 1931-54	1937-38 1933-34	7,601,000 1,900,000	2-28-40 10-4-31	124,000 162	190,000
Klamath River at Klamath	1910-26 1951-54	1951-52 1923-24	18,820,000 3,740,000	1-18-53 7-31-24	285,000 1,340	425,000

and Lost River Basin were considered to be closed basins and as such not contributing to flow of the Klamath River. The estimated seasonal natural flow of the Klamath River at selected stations is shown in Table 11. Estimates of the seasonal natural flow of four principal tributary streams in the Klamath River Basin are presented in Table 12. The magnitude of mean seasonal natural flow of the five streams is shown graphically on Plate 5, entitled "Estimated Seasonal Natural Runoff at Selected Stations in the Klamath River Basin."

Estimates of natural flow of the Klamath River at Keno, near the Oregon-California state line, Klamath River near Klamath, Scott River near Fort Jones, Shasta River near Yreka, Salmon River at Somesbar, and Trinity River near Hoopa, indicate that runoff during the three-year period of investigation was approximately 147 percent of the mean seasonal for the 60-year period, from 1894-95 through 1953-54.

As has been stated, the series of years from October, 1920, through September, 1952, was chosen as the study period for proposed reservoirs. This period was

TABLE 10

ESTIMATED AVERAGE MONTHLY DISTRIBUTION OF NATURAL RUNOFF AT SELECTED STATIONS IN THE KLAMATH RIVER BASIN, 1920-21 THROUGH 1951-52

(In per cent of seasonal total)

Month	Scott River near Fort Jones	Shasta River near Yreka	Klamath River at Keno	Klamath River near Klamath	Salmon River at Somesbar	Trinity River near Hoopa
October	2.0	5.5	6.6	2.3	1.7	1.4
November	4.7	6.9	8.6	5.7	4.8	4.0
December	9.4	9.2	10.2	7.9	9.7	10.6
January	11.0	9.0	9.9	12.2	11.4	12.7
February	11.2	10.8	10.5	16.0	11.8	15.2
March	10.3	10.7	12.9	13.4	13.8	16.7
April	14.7	11.5	13.6	14.6	15.8	15.7
May	17.1	11.1	10.7	12.6	16.4	12.9
June	10.1	8.3	6.0	7.4	9.5	6.8
July	4.3	6.6	2.9	3.5	3.1	2.4
August	3.1	5.5	3.2	2.2	1.2	0.9
September	2.1	4.9	4.9	2.2	0.7	0.7
TOTALS	100.0	100.0	100.0	100.0	100.0	100.0

chosen since it included both the dry period from 1928 to 1935 and an ensuing series of above normal years. Also, throughout the 32-year period data are available to make fairly reliable estimates of runoff.

Records of flow at the stream gaging station established on the Klamath River near Requa in December, 1910, provide a measure of the total outflow to the ocean from the Klamath River Basin. This station was discontinued in June, 1926, but was re-established at approximately the same site in October, 1950, and renamed "Klamath River near Klamath, California."

A stream gaging station on the Klamath River at Keno, Oregon, established in June, 1904, measures, for all practical purposes, the impaired runoff from the Klamath River Basin in Oregon flowing into California. The station is approximately 22 miles above the state line and is located below all major sources of inflow to, and diversion from, the Klamath River. This station was located 6 miles downstream from its present site during the period from October, 1913, to September, 1931. However, 20 months of overlapping record at the two stations indicate that the records at the two sites may be considered equivalent.

Natural flow of the Klamath River is affected by storage in Upper Klamath Lake, extensive irrigation diversions in Oregon, and operation of hydroelectric power plants. Storage on the Shasta River and irrigation in Shasta and Scott Valleys also contribute to the impairment of flow of the Klamath River.

Estimates of the present impaired flow for the period from 1920-21 through 1951-52 at reservoir sites studied during this investigation were based on

TABLE 11

ESTIMATED SEASONAL NATURAL FLOW OF THE KLAMATH RIVER AT SELECTED STATIONS

(In thousands of acre-feet)

Season	Klamath River at Klamath Falls	Klamath River at Keno	Klamath River at Copco	Klamath River near Seiad Valley	Klamath River near Somesbar	Klamath River near Klamath
1894-95	1,760	1,773	2,003	3,668	7,543	16,903
1895-96	1,670	1,683	1,908	3,490	7,110	15,790
1896-97	1,575	1,587	1,812	3,310	6,710	14,745
1897-98	960	970	1,170	2,088	3,938	7,858
1898-99	1,060	1,071	1,276	2,323	4,428	8,993
1899-00	1,400	1,412	1,632	2,987	5,912	12,642
1900-01	1,420	1,432	1,652	3,037	6,012	12,962
1901-02	1,680	1,693	1,918	3,500	7,140	15,865
1902-03	1,525	1,537	1,762	3,225	6,475	14,220
1903-04	2,150	2,165	2,405	4,406	9,221	21,196
1904-05	1,660	1,673	1,898	3,432	6,912	15,227
1905-06	1,670	1,683	1,908	3,489	7,109	15,769
1906-07	2,155	2,170	2,405	4,211	8,486	18,966
1907-08	1,535	1,548	1,763	3,045	5,725	11,805
1908-09	1,675	1,688	1,923	3,778	8,368	19,348
1909-10	1,885	1,898	2,118	3,509	6,649	13,739
1910-11	2,065	2,079	2,304	3,777	7,097	14,907
1911-12	1,690	1,703	1,933	3,319	6,524	11,824
1912-13	1,650	1,663	1,893	3,257	6,137	12,852
1913-14	1,820	1,833	2,063	3,896	6,931	16,326
1914-15	1,350	1,362	1,582	2,996	6,066	14,076
1915-16	1,505	1,517	1,737	3,269	6,619	14,619
1916-17	1,390	1,402	1,622	2,735	5,010	10,136
1917-18	1,175	1,186	1,401	2,161	3,646	7,239
1918-19	1,255	1,266	1,481	2,643	5,428	11,903
1919-20	1,065	1,076	1,226	1,753	3,063	5,603
1920-21	1,670	1,681	1,911	3,652	8,017	16,902
1921-22	1,355	1,367	1,587	2,651	4,726	9,450
1922-23	1,160	1,171	1,381	2,199	3,584	6,940
1923-24	930	940	1,155	1,888	2,538	3,929
1924-25	1,300	1,312	1,502	2,831	6,081	13,551
1925-26	850	860	1,055	2,100	4,050	8,510
1926-27	1,460	1,472	1,712	3,275	6,775	15,005
1927-28	1,240	1,251	1,451	2,668	5,218	11,253
1928-29	915	925	1,120	1,953	3,631	7,109
1929-30	880	890	1,095	2,033	3,908	8,073
1930-31	695	705	860	1,438	2,626	4,878
1931-32	855	865	1,065	2,230	4,520	9,260
1932-33	830	840	1,050	2,265	4,635	9,515
1933-34	740	750	925	1,659	3,110	6,310
1934-35	935	945	1,140	2,321	4,745	10,433
1935-36	1,070	1,081	1,301	2,534	5,193	11,268
1936-37	910	920	1,130	2,212	4,377	9,137
1937-38	1,535	1,547	1,812	4,183	9,717	22,118
1938-39	935	945	1,110	1,981	3,684	7,442
1939-40	1,170	1,181	1,391	2,836	5,888	13,975
1940-41	1,010	1,021	1,231	2,659	5,654	15,243
1941-42	1,155	1,166	1,366	2,854	5,969	14,004
1942-43	1,825	1,838	2,018	3,540	7,870	15,687
1943-44	1,070	1,081	1,291	2,060	3,528	6,873
1944-45	1,090	1,101	1,291	2,515	4,940	10,865
1945-46	1,360	1,372	1,592	3,176	6,691	14,628
1946-47	987	997	1,172	2,010	3,731	7,453
1947-48	1,093	1,101	1,294	2,737	5,576	11,541
1948-49	1,125	1,136	1,338	2,414	4,537	9,830
1949-50	1,190	1,201	1,391	2,715	5,480	11,101
1950-51	1,667	1,680	1,908	4,035	8,288	17,605
1951-52	2,122	2,137	2,475	4,491	9,162	19,164
1952-53	1,818	1,831	2,056	4,066	8,535	17,267
1953-54	2,027	2,041	2,344	4,186	8,675	16,551
60-year mean	1,362	1,374	1,589	2,928	5,832	12,473

TABLE 12

ESTIMATED SEASONAL NATURAL FLOW OF PRINCIPAL TRIBUTARY STREAMS IN THE KLAMATH RIVER BASIN

(In acre-feet)

Season	Shasta River near Yreka	Scott River near Fort Jones	Salmon River at Somesbar	Trinity River at Lewiston	Trinity River near Hoopa
1894-95	217,000	568,000	1,625,000	1,940,000	5,730,000
1895-96	204,000	533,000	1,530,000	1,780,000	5,280,000
1896-97	190,000	493,000	1,450,000	1,610,000	4,850,000
1897-98	120,000	258,000	800,000	675,000	2,240,000
1898-99	129,000	313,000	925,000	825,000	2,640,000
1899-00	167,000	433,000	1,275,000	1,320,000	4,000,000
1900-01	172,000	448,000	1,300,000	1,370,000	4,150,000
1901-02	204,000	533,000	1,540,000	1,790,000	5,310,000
1902-03	180,000	478,000	1,400,000	1,530,000	4,640,000
1903-04	278,000	723,000	1,990,000	2,625,000	7,525,000
1904-05	196,000	508,000	1,480,000	1,680,000	5,040,000
1905-06	203,000	528,000	1,530,000	1,770,000	5,270,000
1906-07	243,000	633,000	1,775,000	2,230,000	6,500,000
1907-08	154,000	408,000	1,180,000	1,170,000	3,600,000
1908-09	252,000	658,000	1,890,000	2,340,000	6,790,000
1909-10	173,000	448,000	1,370,000	1,380,000	4,200,000
1910-11	185,000	483,000	1,420,000	1,550,000	4,700,000
1911-12	143,000	468,000	1,330,000	1,030,000	3,340,000
1912-13	146,000	448,000	1,280,000	1,070,000	3,750,000
1913-14	225,000	578,000	1,600,000	2,030,000	5,530,000
1914-15	235,000	459,000	1,300,000	2,150,000	5,050,000
1915-16	183,000	519,000	1,450,000	1,510,000	4,710,000
1916-17	119,000	349,000	1,050,000	651,000	2,701,000
1917-18	116,000	199,000	600,000	603,000	2,003,000
1918-19	153,000	414,000	1,200,000	1,150,000	3,750,000
1919-20	107,000	165,000	500,000	408,000	1,410,000
1920-21	206,000	620,000	1,700,000	1,800,000	5,400,000
1921-22	127,000	312,000	950,000	784,000	2,784,000
1922-23	121,000	192,000	600,000	686,000	2,086,000
1923-24	101,000	92,000	300,000	266,000	816,000
1924-25	182,000	472,000	1,350,000	1,500,000	4,600,000
1925-26	128,000	282,000	875,000	808,000	2,660,000
1926-27	241,000	532,000	1,500,000	1,830,000	5,130,000
1927-28	160,000	362,000	1,090,000	1,060,000	3,635,000
1928-29	121,000	192,000	593,000	528,000	1,928,000
1929-30	131,000	267,000	825,000	815,000	2,465,000
1930-31	111,000	152,000	473,000	402,000	1,202,000
1931-32	123,000	342,000	1,050,000	720,000	2,690,000
1932-33	123,000	332,000	1,010,000	803,000	2,780,000
1933-34	112,000	187,000	581,000	683,000	1,900,000
1934-35	119,000	382,000	1,134,000	965,000	3,438,000
1935-36	131,000	387,000	1,144,000	1,025,000	3,625,000
1936-37	125,000	322,000	980,000	1,000,000	2,860,000
1937-38	249,000	832,000	2,234,000	2,105,000	7,601,000
1938-39	114,000	242,000	758,000	573,000	2,158,000
1939-40	188,000	442,000	1,277,000	1,613,000	5,137,000
1940-41	261,000	437,000	1,265,000	2,547,000	6,689,000
1941-42	204,000	524,000	1,320,000	1,804,000	5,085,000
1942-43	153,000	629,000	1,735,000	1,108,000	4,467,000
1943-44	123,000	196,000	633,000	654,000	1,995,000
1944-45	144,000	320,000	1,130,000	1,048,000	3,625,000
1945-46	169,000	485,000	1,520,000	1,415,000	4,787,000
1946-47	142,000	246,000	771,000	736,000	2,172,000
1947-48	187,000	376,000	1,238,000	1,209,000	3,465,000
1948-49	160,000	316,000	958,000	1,095,000	3,253,000
1949-50	154,000	370,000	1,179,000	857,000	3,181,000
1950-51	218,000	689,000	1,799,000	1,614,000	5,606,000
1951-52	245,000	767,000	1,953,000	1,821,000	6,413,000
1952-53	253,000	719,000	1,806,000	1,616,000	5,683,000
1953-54	225,000	606,000	1,600,000	1,599,000	5,271,000
60-year mean	171,000	428,000	1,235,000	1,288,000	4,022,000

estimates of natural flow at the principal gaging stations and data from present land and water use surveys.

Once-in-a-thousand year instantaneous flood discharges at gaging stations were estimated from a flood frequency analysis of recorded instantaneous flood flows. Flood hydrographs at recording stations were then developed from a composite of recorded flows and the once-in-a-thousand year instantaneous discharge. These hydrographs were referred to the locations of proposed dams by adjustment in accordance with the ratios of once-in-a-thousand year 24-hour maximum depths of precipitation on the respective drainage areas. These estimates were utilized in the evaluation of spillway capacities for the various projects, and are presented in Chapter IV, "Plans for Water Development."

IMPORTED AND EXPORTED WATER

Water is exported from the Klamath River Basin in Oregon by means of two relatively minor diversions. One diversion is made from Keene Creek by way of Hyatt Prairie Reservoir, and the other from Fourmile Creek by way of the Cascade Canal. The water supply thus diverted provides for the irrigation of lands adjacent to Ashland and Medford in the Rogue River Basin. The quantities of water exported during the period of investigation amounted to about 10,000 acre-feet in 1951-52, 14,900 acre-feet in 1952-53, and 16,200 acre-feet in 1953-54. No water is exported from the Klamath River Basin in California. The only known importation of water into the Klamath River Basin is from the Sacramento River Basin in California. About 4,000 acre-feet seasonally are diverted into the basin and used for irrigation purposes in the extreme southerly end of Shasta Valley.

QUALITY OF WATER

One aspect of the Klamath River Basin Investigation was the determination of the quality of surface and ground waters of the basin with respect to their suitability for present and anticipated beneficial uses. For this purpose, a program of collection and analysis of samples of both surface and ground water from selected areas within the basin was instituted.

Water Quality Criteria

Criteria presented in the following sections are those commonly employed by the Department of Water Resources in evaluating mineral quality of water relative to municipal, domestic, irrigation, and fish and wildlife requirements that are either existing or anticipated for the area under study. It should be pointed out that these criteria are merely guides to the appraisal of water quality. Except for those constituents which are considered toxic to human beings, these criteria should be considered as suggested limiting values. A water which exceeds one or more of

these limiting values need not be eliminated from consideration as a source of supply, but other sources of better quality water should be investigated.

Domestic and Municipal Water Supply. The following tabulation gives the limiting concentrations of mineral constituents for drinking water, as proposed by the United States Public Health Service, and adopted by the State of California:

UNITED STATES PUBLIC HEALTH SERVICE DRINKING WATER STANDARDS, 1946

Constituent	*Mandatory limits in ppm*
Lead (Pb)	0.1
Fluoride (F)	1.5
Arsenic (As)	0.05
Selenium (Se)	0.05
Hexavalent chromium (Cr^{+6})	0.05

	Nonmandatory, but recommended limits
Copper (Cu)	3.0
Iron (Fe) and manganese (Mn) together	0.3
Magnesium (Mg)	125
Zinc (Zn)	15
Chloride (Cl)	250
Sulfate (SO_4)	250
Phenolic compounds in terms of phenol	0.001
Total solids—desirable	500
—permitted	1000

The California State Board of Public Health recently has defined the maximum safe amounts of fluoride ion in drinking water in relation to mean annual temperature.

Mean annual temperature, in °F	*Maximum mean monthly fluoride ion concentration, in ppm*
50	1.5
60	1.0
70-above	0.7

Even though hardness of water is not included in the above criteria, it is of importance in domestic and industrial uses. Excessive hardness in water used for domestic purposes causes increased consumption of soap and formation of scale in pipes and fixtures. The following tabulation for degrees of hardness has been suggested by the United States Geological Survey:

Class	*Range of hardness, expressed as $CaCO_3$, in ppm*	*Relative classification*
1	0– 55	Soft
2	56–100	Slightly hard
3	101–200	Moderately hard
4	201–500	Very hard

Class 1 and 2 waters generally require no softening, while it is desirable to soften, to some degree, those of Classes 3 and 4, depending on use.

Irrigation Water. Criteria for mineral quality of irrigation water used by the Department of Water Resources are those developed at the University of California at Davis and at the United States Department of Agriculture Regional Salinity Laboratory at Riverside. Because of diverse climatological conditions, and the variation in crops and soils in California, only the following general limits of quality for irrigation waters can be suggested:

QUALITATIVE CLASSIFICATION OF IRRIGATION WATERS

Chemical properties	Class I Exellent to good	Class II Good to injurious	Class III Injurious to unsatisfactory
Total dissolved solids:			
in ppm	Less than 700	700-2000	More than 2000
in conductance $EC \times 10^6$ at 25°C	Less than 1000	1000-3000	More than 3000
Chloride, in ppm	Less than 175	175-350	More than 350
Sodium, in percent of base constituents	Less than 60	60-75	More than 75
Boron, in ppm	Less than 0.5	0.5-2.0	More than 2.0

Class I irrigation water is suitable under most conditions for most crops. Class II irrigation water is of doubtful suitability, under certain conditions, for crops of low salt tolerance, including citrus, deciduous fruit, some vegetables, and most clover grasses. Class III water is ordinarily unsatisfactory for all crops except the more tolerant plants such as cotton, sugar beets, and salt-tolerant forage grasses.

These criteria have limitations in actual practice. In many instances a water may be wholly unsuitable for irrigation under certain conditions of use and yet be completely satisfactory under other circumstances. Consideration should be given to soil permeability and drainage, temperature, humidity, rainfall, and other conditions that can alter the response of a crop to a particular quality of water.

Preservation and Protection of Fish and Wildlife. A water of high quality is necessary for preservation and protection of fish and wildlife. This high quality is necessary, not only for the proper environment of fish, but also for maintenance of naturally-occurring food upon which fish depend for survival. Studies by various state and federal agencies show that there are many mineral and organic substances, in relatively low concentrations, which are harmful to fresh water fish and aquatic life. Water quality criteria for maintenance of fresh water fishlife have been suggested by the Department of Fish and Game as follows:

1. Dissolved oxygen content not less than 85 per cent of saturation.
2. Hydrogen-ion concentration (pH) ranging between 6.5 and 8.5.
3. Conductivity between 150 and 500 micromhos at 25°C and in general not exceeding 1,000 micromhos.

Fish and aquatic life are particularly susceptible to:

1. Mineral salts of high toxicity, such as those of mercury, copper, lead, zinc, cadmium, aluminum, nickel, trivalent and hexavalent chromium, and iron. Combinations of these metallic salts sometimes are considerably more toxic to fishlife than any one salt by itself.

2. Detergents, poisons and insecticides employed in agriculture.
3. Unusual temperature conditions. Normal range of water temperature for cold water fish lies between 32° and 65° F. For warm water species, a desirable temperature range is from 45° to 85° F, with an absolute maximum of 91° F.
4. Waste discharges containing more than 15 ppm of ether soluble material.

Water Sampling and Data Collection Program

The water sampling program in the California portion of the Klamath River Basin involved the collection and mineral analyses of 205 surface water samples from 42 streams, and 191 ground water samples from 3 ground water basins.

The surface water sampling program was conducted in two phases. The initial phase, which began in January, 1953, and continued to May, 1953, was undertaken in order to obtain analyses of the streams of the basin during high flows. During this period, samples were collected monthly from 23 streams with 19 additional streams being sampled in May. In order to provide a comparison of water quality during high and low flows, phase two was initiated and involved a resampling of all the streams previously sampled during October, 1953, a period of low surface water flows. In this latter phase, some streams were dry and samples could not be obtained.

Samples were also collected from three small lakes during October, 1953, and analyzed for mineral characteristics. These were Grass Lake, located approximately 16 miles south of Macdoel on Highway 97, and East and West (Salt) Lakes, located approximately 3.5 miles east of Grenada. Samples were also taken monthly from Meiss Lake in Butte Valley during the 1954 irrigation season and analyzed for concentration of mineral constituents.

Ground water samples were obtained during the 1953 sampling periods from 38 wells in Scott Valley, 10 wells along the Klamath River between Shasta and Scott Valleys, 28 wells in Butte Valley, and 75 wells and one spring in Shasta Valley. Samples from these wells and the spring were analyzed for mineral constituents.

Water quality data for the area under investigation were supplemented with data obtained from the statewide periodic stream sampling program and from a water quality survey of the Klamath River stream system made in October, 1950. Other data used during the course of the investigation included ground and surface water analyses obtained from the United States Bureau of Reclamation and from the Quality of Water and Ground Water Branches of the United States Geological Survey.

The North Coastal Regional Water Pollution Control Board, in conjunction with the Oregon State Sanitary Authority, made a pollution survey of the upper portion of Klamath River during the period of May to September, 1953. Samples were collected and analyzed from eight stations in California and one in Oregon.

Quality of Surface Water

Mineral analyses of surface water samples collected in the California portion of the basin during the 1953 season indicate the majority of the streams sampled to be composed of calcium or magnesium bicarbonate type waters of excellent mineral quality, suitable for most domestic and all irrigation uses. Concentrations of total dissolved solids ranged from 70 to 354 parts per million. The waters of some streams exceeded 150 parts per million in hardness, making them less desirable for domestic use. Results of analyses of the quality of surface waters indicate that the suitability of these waters for fish life is excellent in nearly all streams of the basin.

The pollution survey made by the North Coastal Regional Water Pollution Control Board, in conjunction with the Oregon State Sanitary Authority, during the period May to September, 1953, indicated that there was no pollution of the Klamath River in California.

Water sampled from Grass Lake was magnesium calcium bicarbonate in character and had total dissolved solids of 148 parts per million. This water appears to be of excellent quality and suitable for most beneficial purposes.

Analyses of water from East and West Lakes indicate a water of extremely poor quality with total dissolved solids in excess of 1,100 parts per million. Concentrations of boron ranged from 3.6 to 4.0 parts per million and concentrations of sodium were in excess of 90 percent. The source of the poor quality water is not presently known. However, it appears reasonable to assume that because of the volcanic activity which took place in the area in the past, highly mineralized water from magmas is forced surfaceward along a fault zone in the area. Evaporation also undoubtedly contributes to increased concentrations of minerals in the waters.

Samples of water collected from Meiss Lake during the 1954 irrigation season indicate a water of very poor quality. This lake, which forms a natural sump for most of the surface drainage of Butte Valley, has a very high concentration of sodium bicarbonate which causes black alkali in the soil. Total dissolved solids ranged from 473 to 1210 parts per million with per cent sodium fairly constant at about 85.

Results of mineral analyses of representative surface water of the basin are shown in Table 13.

Quality of Ground Water

Results of mineral analyses indicate that ground waters underlying the area are of a bicarbonate type generally suitable for domestic and irrigation uses.

Certain localized areas were found principally in Butte and Shasta Valleys, where ground waters were excessively hard with percentage sodium ranging from 80 to 94 and total dissolved solids between 730 and 1890 parts per million. Some waters had nitrate concentrations which exceeded the recommended limits of 44 parts per million for domestic use. The majority of water from wells having high nitrate concentrations are not properly protected against pollution from the surface, and it is possible for fertilizers, animals, drainage water, and other pollutants to enter the well.

In the northern portion of Shasta Valley, one domestic well evidenced high concentrations of sodium, fluoride, and boron. Because of the unpleasant taste of the water, this well has been abandoned by its owner. The geology of the area indicates that there are fault zones in this vicinity. As in the case of poor quality surface water, it is possible that highly mineralized magmatic waters are forced to the surface along the faults and thus degrade the quality of water in certain wells.

Results of selected mineral analyses of ground water samples from wells in Scott, Shasta and Butte Valleys are presented in Table 14.

Future Water Quality Problems

It is shown in this bulletin that the water supply of the Klamath River Basin as a whole is ample to meet the ultimate water requirements of the basin. However, areas exist within the basin where local water supplies are not adequate to meet ultimate local requirements. This means that for full development of these water deficient local areas, a supplemental water supply must be made available by transfer of water from areas of surplus.

The Butte Valley-Oklahoma District and the Shasta Valley region are two areas which have an ultimate water requirement in excess of their local supplies. Consequently Butte Valley will require an imported supply of supplemental water from the Klamath River to meet increased development in the future. Since Butte Valley is a closed basin, the problem of drainage will become an important item for consideration in plans made for bringing supplemental water into the area. The additional water supply will increase the quantity of surface water drainage. At the present time, surface drainage water collects in Meiss Lake where it is disposed of through evaporation.

When importation of supplemental supplies of water to Butte Valley from Klamath River takes place, the quantity of drainage water that can be re-used for irrigation, after being diluted and freshened by mixing with additional imported Klamath River water, will have to be determined. Also, the quantity of water to be exported out of Butte Valley to maintain a favorable salt balance will have to be provided for.

In addition to the expected future use of Klamath River waters in water-deficient areas within the Klamath River Basin, The California Water Plan makes provision for the exportation of only those waters of the Klamath River system which are surplus to full requirements of the basin to water-deficient areas elsewhere in California. In anticipation of the time when such a transfer of water will become necessary, these waters should be maintained free of pollution. To maintain a suitable water quality will require application of required standards for uses of water in the basin, as well as active cooperation with the State of Oregon on matters affecting the quality of interstate waters. The Klamath River Basin Compact empowers a permanent commission to cooperate with the States of Oregon and California in the establishment of water pollution control requirements and to secure necessary enforcement of such requirements with respect to interstate waters.

Water quality standards considered necessary for the preservation and enhancement of fishlife must be established and maintained if the basin is to continue in its role as a prime sports and recreational area.

A satisfactory answer to these problems will of course require consideration of a physical plan, together with the details of the method of operation, and a basic knowledge of the quality of all water supplies available, local as well as imported. Continued water quality studies, as the plans develop, and as the project is placed in operation, should be one of the major aspects of the water development program.

GROUND WATER

Investigations of the ground water resources of the major valley areas in the Klamath River Basin in California and Oregon were made by the United States Geological Survey, Ground Water Branch, under cooperative agreements with the State of California. In the California portion of the Klamath Basin, the field studies, which commenced in June, 1953, were limited to Butte, Shasta, and Scott Valleys. Although other agricultural areas, such as Hayfork Valley, Hoopa Valley, and the Seiad area, may very well ultimately benefit from ground water development, time and availability of personnel did not permit a ground water investigation of these areas.

The field studies of the California valleys were concluded in the fall of 1954. Reports on Butte and Shasta Valleys are now available in open file status in the offices of the Geological Survey, and the Scott Valley report has been printed as Water-Supply Paper 1462. A summary of the geologic characteristics of the Klamath River Basin is presented in Appendix A, and maps of geologic and ground water conditions in Butte, Shasta, and Scott Valleys are bound at the end of this bulletin.

A study of ground water conditions of the valley regions in the Oregon portion of the Klamath Basin was made in 1954 and 1955 by the Geological Survey

TABLE 13

MINERAL ANALYSES OF SURFACE WATER [a] IN THE KLAMATH RIVER BASIN

Source	Location number	Date sampled	Discharge in cfs	Temp. in °F.	Specific conductance (micromhos at 25° C)	pH	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Fluoride (F)	Boron (B)	Silica (SiO_2)	Other constituents [c]	Total [b] dissolved solids in ppm	Percent sodium	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ N.C. ppm	Remarks [d]
							Mineral constituents in parts per million / equivalents per million																	
	WB&M																							
Williamson River at Chiloquin	34S/7E-34K	4/23/53	--	52	98	7.0	5.8	3.8	9.6	1.8	0	44	13	0.8	1.2	0.3	0.07	26		84	39	30	0	
							0.29	0.31	0.42	0.05	0.00	0.72	0.27	0.02	0.02	0.02								
Klamath River at Keno	39S/8E-31P	10/12/50	--	--	235	9.1	12	7.6	26	9.2	14	62	41	9.0	0.5	--	0.2	24		174	44	61	0	
							0.60	0.62	1.13	0.24	0.47	1.02	0.85	0.25	0.01									
Miller Creek near Lorella	40S/14E-7K	4/23/53	--	51	64	7.2	5.6	3.2	4.1	1.3	0	40	1.3	0.8	0.6	0.3	0.00	18		55	24	27	0	
							0.28	0.26	0.18	0.03	0.00	0.66	0.03	0.02	0.01	0.02								
	MDB&M																							
Butte Creek near Macdoel	45N/1W-29G	9/25/53	4.7	56	78	7.1	6.9	3.6	4.1	1.4	0	49	1.6	1.0	0.3	0.2	0.01	27		70	21	32	0	
							0.34	0.30	0.18	0.04	0.00	0.80	0.03	0.03	0.01	0.01								
Meiss Lake	46N/2W-2E	6/ 9/54	--	--	747	7.9	17	12	148	11	0	476	6.8	14	0.8	0.2	0.11	29		473	75	92	0	
							0.85	0.99	6.44	0.28	0.00	7.80	0.14	0.39	0.01	0.01								
		9/21/54	--	--	1,920	9.0	16	18	432	30	110	1,050	14	48	4.0	1.4	0.11	24		1,210	86	112	0	
							0.80	1.44	18.79	0.77	3.67	17.21	0.29	1.35	0.06	0.07								
Klamath River near Copco	48N/5W-36G	5/ 3/54	3,520	55	121	7.2	9.3	3.6	9.0	1.8	0	54	9.4	2.5	2.0	0.0	0.07	20	Fe 0.07, Al 0.01	84	33	38	0	PSSP Sta. #1
							0.46	0.30	0.39	0.05	0.00	0.89	0.20	0.07	0.03	0.00								
		9/ 3/54	3,250	65	185	7.8	12	5.8	17	3.0	0	84	15	4.0	4.1	0.3	0.09	37	Fe 0.10, Al 0.01, Cu 0.01, Zn 0.01, PO_4 0.60	139	39	54	0	
							0.60	0.48	0.74	0.08	0.00	1.38	0.31	0.11	0.07	0.02								
Shasta River at Edgewood Bridge	42N/5W-20J	10/ 1/53	11	58	252	7.6	10	19	16	2.0	0	152	3.6	6.0	0.4	0.2	0.09	46		178	25	103	0	
							0.50	1.56	0.70	0.05	0.00	2.49	0.08	0.17	0.01	0.01								
Little Shasta River near Little Shasta	45N/4W-15C	5/27/53	111	41	76	7.3	7.5	2.7	4.3	0.9	0	46	3.2	0	0.5	0.1	0.04	29		71	23	30	0	
							0.37	0.22	0.19	0.02	0.00	0.75	0.07	0.00	0.01	0.01								
Greenhorn Creek near Yreka	45N/7W-34E	5/28/53	7	55	356	8.1	37	23	4.5	1.1	0	211	22	1.2	0.2	0.0	0.00	17		210	5	187	14	
							1.85	1.89	0.20	0.03	0.00	3.46	0.46	0.03	0.00	0.00								
Shasta River near Yreka	46N/7W-24H	5/28/53	462	59	515	8.2	22	38	36	3.0	0	312	10	16	1.2	0.3	0.19	40		320	27	211	0	
							1.10	3.12	1.57	0.08	0.00	5.11	0.21	0.45	0.02	0.02								
		10/ 2/53	134	55	549	8.4	34	30	42	3.4	10	296	7.8	26	0.4	0.3	0.52	54		354	30	208	0	
							1.70	2.47	1.83	0.09	0.33	4.85	0.16	0.73	0.01	0.02								

Klamath River above Gottville	46N/8W-1M	10/ 2/53	2,800[e]	58	196	7.4	13	7.3	16	2.5	0	95	10	5.2	4.9	0.1	0.06	38		144	35	62	0	
							0.65	0.60	0.70	0.06	0.00	1.56	0.21	0.15	0.09	0.01								
East Fork Scott River at Callahao	40N/8W-16N	9/30/53	9.2	58	257	7.8	19	20	4.5	0.9	0	157	6.1	3.5	0.2	0.1	0.04	22		154	7	130	1	
							0.95	1.65	0.20	0.02	0.00	2.57	0.13	0.10	0.00	0.01								
Scott River near Fort Jones	44N/10W-28D	5/22/53	1,600	46	112	7.4	11	6.4	2.0	0.5	0	66	4.0	0.5	1.0	0.1	0.03	13		71	7	54	0	
							0.55	0.53	0.09	0.01	0.00	1.08	0.08	0.01	0.02	0.01								
		9/30/53	105	62	281	7.8	32	14	4.9	0.7	0	167	6.6	4.0	2.2	0.0	0.00	19		166	7	137	1	
							1.60	1.15	0.21	0.02	0.00	2.74	0.14	0.11	0.04	0.00								
Klamath River above Seiad Valley	46N/12W-13A	10/ 2/53	3,000[e]	--	185	7.4	12	7.4	15	2.5	0	86	12	6.5	5.4	0.1	0.16	34		137	34	60	0	
							0.60	0.61	0.65	0.66	0.00	1.41	0.25	0.18	0.09	0.01								
	HB&M																							
Salmon River near Somesbar	11N/6E-3G	10/12/50	125[e]	--	120	8.5	16	4.1	3.4	3.2	0	67	4.9	2.5	0.0	--	0.04	14		81	11	57	2	
							0.80	0.34	0.15	0.08	0.00	1.10	0.10	0.07	0.00									
Klamath River at Somesbar	11N/6E-4H	5/ 5/54	14,800	62	106	7.7	11	4.2	4.1	0.8	0	58	5.0	1.6	0.6	0.0	0.10	16	Fe 0.04, Al 0.04, Zn 0.02	72	16	45	0	PSSP Sta. #2
							0.55	0.35	0.18	0.02	0.00	0.95	0.10	0.05	0.01	0.00								
		9/15/54	4,350	64	210	7.4	15	7.9	16	2.8	0	98	14	5.2	2.1	0.3	0.11	33	Fe 0.04, Al 0.01, Cu 0.01, Zn 0.01, As 0.01	144	32	70	0	
							0.75	0.65	0.69	0.07	0.00	1.61	0.29	0.15	0.03	0.02								
	MDB&M																							
Trinity River at Lewiston	33N/8W-19H	5/12/53	3,520	52	78	7.4	5.0	6.7	1.6	0.3	0	49	2.3	1.5	0.2	0.0	0.03	14		56	8	40	0	PSSP Sta. #4a
							0.25	0.55	0.07	0.01	0.00	0.80	0.05	0.04	0.00	0.00								
		9/16/53	235	62	147	7.3	9.0	9.9	4.1	0.5	0	76	3.1	4.5	0.2	0.0	0.06	15	Fe 0.01, Zn 0.01	84	12	63	1	
							0.45	0.81	0.18	0.01	0.00	1.25	0.07	0.13	0.00	0.00								
	HB&M																							
Hayfork Creek at Hyampom	3N/6E-25C	10/22/50	40	--	335	8.3	34	16	14	2.2	0	156	8.4	28	0	--	0.06	19		198	17	151	23	
							1.70	1.32	0.61	0.06	0.00	2.56	0.18	0.79	0.00									
South Fork Trinity River near Salyer	6N/5E-27A	10/18/50	130[e]	--	336	8.6	31	12	8.0	4.4	26	88	13	10	0.2	--	0.08	16		164	12	126	11	
							1.55	0.99	0.35	0.11	0.87	1.44	1.27	0.28	0.00									
Trinity River near Hoopa	8N/5E-31K	5/ 5/53	11,800	59	112	7.3	13	5.2	2.2	0.4	0	66	4.4	2.5	0.2	0.1	0.00	14		74	8	54	0	PSSP Sta. #4
							0.65	0.43	0.10	0.01	0.00	1.08	0.09	0.07	0.00	0.01								
		9/16/53	840	76	197	7.5	20	9.7	4.8	0.6	0	105	8.1	5.5	0.2	0.0	0.04	14		115	10	90	4	
							1.00	0.80	0.21	0.02	0.00	1.72	0.17	0.16	0.00	0.00								
Klamath River near Klamath	13N/2E-17N	5/ 5/54	21,600	59	120	7.1	12	5.9	3.2	0.6	0	64	5.4	1.6	0.3	0.0	0.07	15	Fe 0.03, Al 0.04, Zn 0.04	76	11	54	2	PSSP Sta. #3
							0.60	0.48	0.14	0.02	0.00	1.05	0.11	0.01	0.01	0.00								
		9/15/54	5,500	66	192	7.8	17	7.2	11	1.8	0	94	11	4.8	1.3	0.2	0.06	25	Fe 0.03, Cu 0.01, Zn 0.01, As 0.01	125	21	72	0	
							0.85	0.59	0.18	0.05	0.00	1.54	0.23	0.14	0.02	0.01								

[a] Analyses by United States Geological Survey, Quality of Water Branch, Sacramento Laboratory
[b] Calculated from analyzed constituents.
[c] Iron (Fe), aluminum (Al), manganese (Mn), chromium (Cr), copper (Cu), lead (Pb), zinc (Zn), arsenic (As) not analyzed for except as shown.
[d] Department of Water Resources Periodic Stream Sampling Program (PSSP).
[e] Estimated.

TABLE 14

MINERAL ANALYSES OF GROUND WATER[a] IN THE KLAMATH RIVER BASIN

Source and type	Well number	Date sampled	Temp. in °F.	Specific conductance (micromhos at 25°C)	pH	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Fluoride (F)	Boron (B)	Silica (SiO_2)	Other constituents[c]	Total[b] dissolved solids in ppm	Percent sodium	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ N.C. ppm	Remarks
						Mineral constituents in parts per million / equivalents per million																	
BUTTE VALLEY																							
Delos Mills Irrigation Well	45N/2W-3H1	10/ 1/53	52	277	7.2	17	13	24	5.2	0	166	3.7	1.8	8.3	0.1	0.05	49		204	34	96	0	
						0.85	1.07	1.04	0.13	0.00	2.72	0.08	0.05	0.13	0.01								
Cross Stock & Irrigation Well	46N/1E-8E1	5/13/53	52	356	7.3	26	18	17	5.5	0	152	11	15	24	0.0	0.03	51	Fe (total) 0.1	242	20	139	14	depth 200′
						1.30	1.48	0.74	0.14	0.00	2.49	0.23	0.42	0.39	0.00								
Butte Valley I.D. Irrigation Well	46N/1W-19J1	5/13/53	53	268	7.5	18	17	11	3.8	0	160	10	2.5	0.7	0.2	0.01	46	Fe (total) 0.0	188	17	115	0	depth 61′
						0.90	1.40	0.48	0.10	0.00	2.62	0.21	0.07	0.01	0.01								
City of Dorris Municipal Well	48N/1E-30N1	5/13/53	56	345	7.5	16	20	24	7.7	0	188	15	8.5	7.3	0.3	0.06	41	Fe (total) 0.0	232	28	122	0	
						0.80	1.64	1.04	0.20	0.00	3.08	0.31	0.24	0.12	0.02								
		10/ 1/53	54	277	8.0	12	14	23	7.3	0	158	10	2.5	1.4	0.3	0.05	38		186	34	88	0	H_2S present
						0.60	1.15	1.00	0.19	0.00	2.59	0.21	0.07	0.02	0.02								
SHASTA VALLEY																							
J. W. King Domestic Well	42N/5W-33M3	5/11/53	--	463	7.6	10	54	8.7	1.5	0	284	7.4	7.8	11	0.0	0.00	55	Fe (total) 0.0	295	7	247	14	depth 148′ perforated 68′-148′
						0.50	4.44	0.38	0.04	0.00	4.65	0.15	0.22	0.18	0.00								
Dougherty Irrigation Well	43N/6W-22M1	5/11/53	58	457	8.1	57	25	9.2	1.1	0	302	8.1	2.0	4.8	0.0	0.05	30	Fe (total) 0.0	286	8	245	0	depth 250′
						2.84	2.06	0.40	0.03	0.00	4.95	0.17	0.06	0.08	0.00								
Henry Silva Irrigation Well	44N/5W-34H1	5/ 8/53	56	634	7.3	42	33	44	5.2	0	368	7.6	21	8.0	0.1	0.26	66	Fe (total) 0.0	408	28	240	0	depth 96′
						2.10	2.71	1.91	0.13	0.00	6.03	0.16	0.59	0.13	0.01								
Stan Cooley Irrigation Well	46N/6W-25G1	5/ 7/53	58	593	7.0	47	28	16	2.6	0	388	1.2	5.0	3.5	0.5	0.10	32	Fe (total) 23	350	13	232	0	depth 235′
						2.35	2.30	0.70	0.07	0.00	6.36	0.02	0.14	0.06	0.03								
SCOTT VALLEY																							
W. N. Wolford Domestic Well	41N/9W-25G1	5/12/53	--	531	7.6	96	11	5.8	0.4	0	338	4.4	3.5	11	0.0	0.01	28	Fe (total) 0.0	327	4	284	8	depth 50′ (approx.)
						4.79	0.90	0.25	0.01	0.00	5.54	0.09	0.10	0.18	0.00								
Bessie Beeson Domestic Well	43N/9W-11H2	5/12/53	--	256	7.1	23	15	6.1	0.6	0	128	8.1	2.2	16	0.2	0.00	29	Fe (total) 0.0	163	10	119	14	depth 51′
						1.15	1.23	0.26	0.02	0.00	2.10	0.17	0.06	0.26	0.01								
Al and Joe King Stock Well	43N/9W-28D1	5/12/53	58	140	6.8	16	6.2	40	1.6	0	82	2.8	1.0	0.2	0.0	0.08	15	Fe (total) 0.0	87	11	65	0	depth 41′
						0.80	0.51	0.17	0.04	0.00	1.34	0.06	0.03	0.00	0.00								
John Stanton Emergency Domestic Well	44N/8W-31G1	5/12/53	48	505	7.3	37	42	6.1	1.9	0	156	140	1.2	0.4	0.1	0.01	21	Fe (total) 0.0	326	5	265	137	depth 30′ dug well
						1.85	3.45	0.27	0.05	0.00	2.56	2.91	0.03	0.01	0.01								

[a] Analyses by United States Geological Survey, Quality of Water Branch, Sacramento Laboratory.
[b] Calculated from analyzed constituents.
[c] Iron (Fe), aluminum (Al), manganese (Mn), copper (Cu), lead (Pb), zinc (Zn), arsenic (As), chromium (Cr), not analyzed for, except as shown.

with the United States Bureau of Reclamation as an additional cooperator. A preliminary report resulting from these studies in Oregon is also included in Appendix A.

The purposes of the ground water investigations were to obtain basic information relating to the extent, character, and thickness of the water-bearing formations; to determine the availability and quantities of ground water for domestic, stock, and irrigation supplies; to ascertain the geologic factors that control the occurrence and movement of ground water; and to determine the chemical character of the ground water and its relation to the occurrence, movement, and beneficial uses of such water. Insofar as practicable, the storage capacity and safe yield of the basins were determined.

Butte Valley Region

The area included in the ground water investigation of the Butte Valley Region comprised the main valley floor of Butte Valley as well as the geologically related area of the Oklahoma District and Red Rock Valley. The geologic formations in the Butte Valley Region are shown on Plate 6.

The volcanic rocks of the Butte Valley Region are generally more permeable than the sedimentary formations and form an important ground water reservoir. They contain few wells, but are generally fractured and quite permeable, and have high infiltration and storage capacity. The Pliocene diatomite deposits, on the other hand, have low permeability and act as confining beds for water contained in underlying sedimentary or volcanic rocks.

Lake deposits of varying permeability underlie much of the portion of Butte Valley referred to as the Macdoel Subunit. In the area generally west of U. S. Highway 97, these deposits consist principally of clays and are relatively impermeable. East of Highway 97, especially along the eastern border of the valley, the lake deposits contain much larger quantities of sand, and their permeability coefficients range from about 140 to 250 gallons per day per square foot. Coefficients were determined from drawdown and recovery tests of three pumped wells and from a study of comparative yield factors.

The Butte Valley basalt in the southern part of Butte Valley is the most productive water-bearing formation in the region. Yields of more than 100 gallons per minute for each foot of drawdown are not uncommon, and yields of 1,000 gallons per minute for each foot of drawdown have been recorded.

The late Pleistocene and Recent volcanic rocks are important chiefly as formations which receive recharge to ground water from the surface. The alluvium is poorly sorted and generally not very productive of water. Blocky talus debris occurs principally at the foot of precipitous fault scarps and, where buried and interfingered with water-saturated sediments, it forms a permeable part of the ground water reservoir.

Ground water in Butte Valley generally moves among the various water-bearing formations without significant changes in level at formation contact, except insofar as such changes are caused by differences in permeability. Ground water recharge results mainly from influent seepage from perennial spring-fed streams and unlined canals in the southern part of the region, and from small spring-fed streams discharging into alluvial fans along the western margin of Butte Valley. Infiltration of precipitation falling on the valley floor also provides a small amount of ground water recharge.

Ground water movement is believed to occur in the southern part of Butte Valley, generally eastward and northeastward across the valley from the volcanic rocks of the High Cascades into the Butte Valley basalt. Natural subsurface outflow apparently occurs at the northeastern edge of the valley, where the ground water appears to move into buried talus and fractured volcanic bedrock, from whence its direction of movement is uncertain. Some or all of this may reach the surface on the eastern side of the Mahogany Ridge scarp, where there are a number of flowing springs and wells that supply water to the Oklahoma District.

The land surface in Butte Valley is about 140 feet higher than the general land surface in the Oklahoma District. Based on intermittent measurements, it has been estimated that seasonal flow from springs, including those flowing into Hot Creek, Cottonwood Creek, and Willow Creek amounts to about 26,000 acre-feet. However, pumping for irrigation in Butte Valley, amounting to about 22,000 acre-feet seasonally, is the principal well-defined means of depletion of the ground water basin in Butte Valley. Lines of equal elevation of ground water in Butte Valley for the spring of 1954 are shown on Plate 8.

In Red Rock Valley, southeast of Butte Valley, ground water extractions were negligible until 1954, when three wells were drilled for irrigation. In the Oklahoma District, ground water is discharged by flowing wells, by springs, and by pumping for irrigation and domestic requirements. Because of the small number of wells and lack of water level measurements, the configuration of the basins and the direction of ground water movement in Red Rock Valley and the Oklahoma District have not been determined.

The quality of the ground water in the Butte Valley Region is generally satisfactory for ordinary uses. However, in the east central part of Butte Valley, some irrigation wells encounter waters containing high percentages of sodium, which are probably derived from buried playa deposits.

Monthly measurements of depth to ground water have been made by the United States Bureau of Reclamation from the fall of 1951 to the present (1958), except for the period from the fall of 1953 to the fall of 1954 when this was done by the United

States Geological Survey as a part of this investigation. Analysis of these water level measurements shows that the depth to ground water increases between spring and fall. These fluctuations range from 1 to 2 feet in the central and eastern parts of the valley, from 2 to 4 feet in the southern portion, and from 3 to 5 feet along the northern border. A comparison of either fall or early spring water levels in successive years indicates that there is little net change in the ground water storage from season to season. Similarly, it has been found that there was no significant change in ground water storage between the fall of 1951 and the fall of 1954.

A hydrologic analysis of water supply and disposal was made for the purpose of approximating the relationship between the use of water under present conditions and the mean water supply available. It also served the purpose of estimating the approximate quantity of ground water outflow under present conditions of development. Items involved in the hydrologic analysis, presented in Table 15 for the Macdoel Subunit No. 5A, consisted of the following:

1. Surface seasonal inflow was estimated for the 60-year mean period by correlating the short-term record on Butte Creek and intermittent measurements on the minor west side streams with nearby streams of longer record.
2. Subsurface inflow was determined as the difference between the seasonal volume of the 50-year mean seasonal precipitation on the watershed less estimated seasonal surface runoff and estimated seasonal consumptive use by native vegetation.
3. Precipitation on the valley floor was determined from a 50-year mean seasonal isohyetal map.
4. Present mean seasonal consumptive use of water was estimated for irrigated and urban lands; evaporation from water surfaces, including evaporation losses from distribution systems; and evapo-transpiration from dry farm and non-agricultural land within the valley area. Consumptive use includes both applied water and precipitation. Land use data and unit values of consumptive use are presented elsewhere in this bulletin.
5. There is no surface outflow from Butte Valley.
6. Measured change in ground water storage between 1951 and 1954, inclusive, was negligible. To the knowledge of residents who have been familiar with water conditions in Butte Valley since the early 1900's, there has been no significant increase or decrease in depth to ground water. It was therefore assumed that under present conditions of development, there would be no progressive change in ground water storage.

The difference between items of seasonal water supply and items of its seasonal disposal, aggregating 41,000 acre-feet, includes subsurface outflow plus the residual sum of possible errors in other estimated quantities. As previously stated, a seasonal surface discharge of about 26,000 acre-feet occurs along the northeastern edge of Mahogany Mountain outside Butte Valley proper. Although this is probably the major part of the subsurface outflow from the valley, there probably is also additional subsurface outflow discharging directly into the ground water basins of the Oklahoma District and Lower Klamath Lake. Thus, the ground water outflow was estimated to be in the order of magnitude indicated by the above hydrologic analysis.

Surface and ground water available for irrigation and domestic purposes was deduced as follows:

1. Total mean seasonal consumptive use of precipitation was estimated to be 10,000 acre-feet from irrigated and urban lands, 4,000 acre-feet from water surfaces and marsh lands, and 71,000 acre-feet from native and dry farm lands, a total of 85,000 acre-feet.
2. Substracting this amount from the total mean seasonal water supply of 150,000 acre-feet leaves the amount of water available for surface application and ground water recharge, about 65,000 acre-feet.
3. The amount of water remaining for surface diversion and ground water extraction, after subtracting the computed subsurface outflow of 41,000 acre-feet is 24,000 acre-feet. It must be recognized that this figure is the result of the previously set forth estimates of water supply and water use, and is indicative of the general magnitude of the mean seasonal water supply available for use in the Macdoel Subunit under existing conditions of development.

Additional use of the available water supply will tend to lower ground water levels which may in turn result in decreased subsurface outflow, with a corresponding increase in the supply which can be utilized in the unit without producing an overdraft.

The present amount of water applied on irrigated and urban lands, based on data collected during 1952-53 and 1953-54, was about 27,000 acre-feet seasonally. Runoff during both of these seasons was above

TABLE 15

HYDROLOGIC ANALYSIS OF MACDOEL SUBUNIT 5A, BUTTE VALLEY

	Mean seasonal quantity, in acre-feet
Water Supply	
Surface inflow	18,000
Subsurface inflow	38,000
Precipitation on valley floor	94,000
Total mean seasonal water supply	150,000
Water Disposal	
Consumptive use on irrigated and urban lands	22,000
Evaporation from water surfaces and marsh lands	16,000
Consumptive use on native and dry farm land	71,000
Surface outflow	0
Subsurface outflow	unknown
Change in ground water storage	0
Total present seasonal water disposal	109,000
Difference between water supply and disposal	41,000

normal and adequate to meet the demands of the existing works. About 5,000 acre-feet were secured from surface diversions and the remaining 22,000 acre-feet were pumped from ground water.

Shasta Valley

The areal extent of the Shasta Valley geologic formations is shown in Plate 9. The pre-Cretaceous, Upper Cretaceous, and Eocene formations in Shasta Valley are tapped by relatively few wells. Yields are low, but are sufficient in most instances for domestic and stock supplies. Permeable zones in the pre-Cretaceous rocks occur in the form of structural openings such as joints, faults, shear zones, and foliation planes. The Western Cascade andesitic lavas generally supply sufficient water for domestic and stock supplies; however, the yields of wells tapping the andesites vary greatly because of rapid changes in permeability, both laterally and vertically. Abundant water for irrigation is yielded by fractured Western Cascade lava in the Gazelle-Grenada area.

The Pluto's Cave basalt constitutes the best and most consistent aquifer in the valley, yielding abundant water to irrigation, stock, and domestic wells in the vicinity of Big Springs. Water in the basalt occurs in joint cracks that were formed by shrinkage in the rough broken rock during cooling between successive lava flows, at the edges of flows, and in lava tunnels now partly filled with debris fallen from sides and top. Yields of irrigation wells in the basalt range from 100 to 4,000 gallons per minute and average about 1,300 gallons per minute.

The permeability of glacial moraine and outwash deposits varies greatly over short distances. Irrigation wells tapping glacial materials east of Edgewood have yields ranging from 600 to 1,500 gallons per minute. Most of the wells tapping recent alluvium are shallow dug wells used for domestic and stock supplies, although a few wells in alluvium along the west side of the valley provide water for irrigation and supply the City of Yreka with water for municipal purposes. Elevations of water levels in Shasta Valley are shown on Plate 11.

The main recharge to the ground water body takes place principally from the northwest slopes of Mount Shasta, by deep infiltration of precipitation falling on the tributary drainage area. In the southern part of Shasta Valley ground water moves generally northward and toward the valley axis, where all gradients indicate that Shasta and Little Shasta Rivers are effluent streams. At the north end of the valley, an east-west ground water divide separates ground water moving north to Willow Creek from ground water moving south to the Shasta River.

The total seasonal pumpage of ground water in the valley is estimated for 1953 to be approximately 5,500 acre-feet, of which about 2,000 acre-feet is used for irrigation. This can be compared with the total surface water applied for irrigation, of approximately 57,500 acre-feet per season.

Seasonal ground water discharge in 1953 in Shasta Valley was estimated to be on the order of 130,000 acre-feet. The four principal estimated mean seasonal amounts of discharge are: (1) seepage into streams, 70,000 acre-feet, (2) discharge from Big Springs, 30,000 acre-feet, (3) evapo-transpiration from subirrigated crops, 28,000 acre-feet, and (4) net pumpage from ground water, 4,000 acre-feet. In addition, minor discharge occurred from flowing wells and small springs, and as evapo-transpiration losses from small areas of phreatophytes.

Surface and ground waters in Shasta Valley are generally of low mineral content and meet suitable standards in most cases for irrigation use. Except for the hardness criteria they also meet the standards for domestic use. A close correlation is evident between the composition of the various rock types in Shasta Valley and the mineralization of water samples.

Scott Valley

The areal extent of the geologic formations in Scott Valley is shown in Plate 12. The Scott Valley ground water basin, except for minor portions underlying Moffett and McAdam Creeks and Hamlin Gulch, occupies an area of about 35,700 acres. The basin is surrounded by mountain ranges, is 22 miles long in a north-south direction, and varies from less than a mile to as much as five miles in width. For purposes of geologic study, the ground water basin was subdivided into four zones each having separate characteristics: (1) the Scott River flood plain, (2) the discharge zone at the eastern edge of the western mountain fans, (3) the western mountain fans and Oro Fino Valley, and (4) Quartz Valley.

The Scott River flood plain, the principal ground water zone in the valley, extends in a narrow band up to two miles wide along the river channel, from about four miles south of Etna to the outlet of the valley north of the mouth of Shackleford Creek. This portion of the basin is composed mainly of Recent alluvium with a maximum depth of over 400 feet. The land surface slopes gently from an elevation of about 2,900 feet at the southern end of the area to an elevation of about 2,700 feet at the northern extremity. The water table follows a configuration similar to the ground surface, and occurs at depths varying from the surface to as much as 35 feet below ground surface. Average depth to ground water is about ten feet. Ground water moves northward from Callahan to the valley outlet, and also from the margins of Scott Valley toward the river, where ground water discharge supplements the flow of Scott River. The river flows in a channel less than 10 feet below the valley ground surface and induces a slight trough in the ground water surface. The main recharge areas to the Scott River flood plain zone are the fans on the western side and southern portion of Scott Valley. The Scott River does not, under present conditions, contribute to ground water storage, but rather acts as a drain for the high water table lands throughout the valley.

Several large irrigation wells drilled in the Scott River flood plain between Etna and Fort Jones yield from 1,200 to 2,500 gallons per minute. Estimated coefficients of permeability for the recent alluvium in this zone range from 600 to 1,800 gallons per day per square foot. The average specific yield of the flood plain deposits is estimated at 15 per cent. Ground water storage capacity for the zone from 10 feet to 100 feet below land surface for the Scott River flood plain has been estimated to be more than 200,000 acre-feet.

The streams discharging from the Salmon Mountains onto the western side of the valley have built up a complex system of alluvial deposits. Coarse permeable gravels have been deposited in fans at the base of the mountains, while finer less permeable sediments have been carried out into the valley. In the central part of Scott Valley, between Etna and Fort Jones, these deposits are termed the western mountain fan zone and the discharge zone, respectively.

The discharge zone occupies about 6,500 acres to the west of the Scott River flood plain zone. It extends from about one mile north of Etna to about two miles north of Greenview, a distance of about eight miles, with an average width of about one and one-half miles. To the west of this zone, the western mountain fan zone occupies an area of 8,400 acres between the discharge zone and the mountains bordering Scott Valley on the west. From Etna Creek on the south, the western mountain fan zone extends northward through Oro Fino Valley.

The western mountain fans and their extension into Oro Fino Valley are composed of coarse stream channel deposits which have built up from streams discharging onto the valley floor. Most of the existing and former streams radiating from the fans are blocked some distance out in the valley by the finer sediments deposited beyond the fans. Much of the surface runoff of streams, including Kidder, Patterson, Crystal, and Etna Creeks, contributes to the ground water in these fan areas. This recharge, however, must pass through the less permeable discharge zone in the center of the valley or rise to the surface to pass over it. Although much of the buried gravels are confined, it is probable that some of the interlayered gravels extend into the Scott River flood plain zone and provide rapid recharge to that zone.

The western mountain fan zone varies considerably in both depth and permeability. Extreme changes have been observed in the yield characteristics of wells only short distances apart. Depths of water-bearing material, however, generally exceed 100 feet and the average specific yield is estimated to be about seven per cent. Depth to ground water averages about 15 feet in this zone, and the water moves eastward at gradients estimated to be 25 to 30 feet per mile.

The discharge zone is composed of fine sediments, and is so named because these impervious materials block the older buried coarse stream channels and force the ground water to rise to the surface along the western edge. In a number of places the ground water is confined and produces artesian flow in wells for at least part of the year. The water table varies from the surface to a depth of about 15 feet. The water table slopes toward the discharge area at gradients varying from 25 to less than 10 feet per mile. The average specific yield has been estimated to be about five per cent. Where the water table rises to the ground surface, swampy areas may occur. In some places where the water table does not reach the surface, this condition is utilized to provide sub-irrigation for crops.

Quartz Valley is a separate ground water basin, some 4,800 acres in extent, tributary to the Scott River flood plain zone at its extreme northern end. Mill Creek and Shackleford Creek, which discharge from the Salmon Mountains into this valley, have built up an extensive body of Recent alluvium. The deposits are composed of coarse gravels in the fan areas, and finer material intermixed with the gravels in the center of the valley. The water table follows the surface configuration and slopes rather steeply northward at gradients up to 60 feet per mile. The depth of water-bearing material is estimated to exceed 100 feet in the center of the valley. It is estimated that the average specific yield is about 15 per cent. There has been no development of wells in this area other than for domestic, stock, and garden purposes.

Surface water is much more extensively used than ground water for irrigation in Scott Valley. The total seasonal ground water extraction in 1953 was estimated to be about 1,500 acre-feet, of which about 900 acre-feet was used for irrigation. Surface and ground waters are of low mineral content and are generally of excellent quality for all uses.

Klamath River Basin in Oregon

The principal water-bearing formations in the Klamath River Basin in Oregon, from oldest to youngest, are the lower lava rocks, certain zones in the Yonna formation, the upper lava rocks, (the foregoing all being units of the High Cascade series), Quaternary alluvium, and Quaternary pumice.

Logs of wells penetrating the lower lava rocks show about one-third of that formation as "porous, water-bearing." These rocks lie beneath the less pervious Yonna formation, and consequently cannot obtain appreciable recharge from the surface. However, they do obtain significant recharge from the slopes of the Cascades and from the exposed edges of the other fault blocks. The upper lava rocks are generally more permeable than the lower lava rocks, about two-thirds of this unit being classified in Yonna and Swan Lake Valleys as "porous, water-bearing rock." The upper lava rocks are open to recharge from the surface at most places.

Quaternary alluvium, where present, is generally rather fine grained, but has sufficient permeability to yield moderate amounts of water to wells in some areas. In Swan Lake Valley the alluvium contains a perched water body. Water percolates underground to the regional water table from the south, west, and east sides of this body of water. The extensive areas of Quaternary pumice have very high infiltration rates, and serve principally as areas of intake for transmittal of ground water to underlying and adjacent formations.

The main ground water body of the Klamath River Basin in Oregon is continuous, both vertically between formations and horizontally throughout the basin, and has a base level near that of the major streams. Divides between the various hydrologic units, although not severing connection between parts of this ground water body, makes possible separation of the main ground water body into four segments: the Williamson River, Sprague River, Lost River, and Upper Klamath Lake Hydrologic Units.

In the northern part of the Williamson River Hydrologic Unit, ground water generally moves both from the east and the west toward the plain extending north of Klamath Marsh. Some of this ground water is discharged to the surface at Big Springs at the upper end of Klamath Marsh. Ground water west of Klamath Marsh moves, in part, to the south beneath the pumice plain, at a gradient of 5 to 10 feet per mile. This gradient becomes steeper to the south near Spring Hill and the Wood River Valley. Ground water is largely discharged to the surface at Wood River Springs, Fish Hatchery Springs, and Spring Creek Springs.

In the Sprague River Hydrologic Unit, ground water between the communities of Sprague River and Beatty moves generally toward the east-west trending trough of the valley from both the north and the south, with some westward movement down the valley. Ground water divides occur between the Sprague River Valley and Yonna Valley on the south, and between the Sprague River Valley and the Klamath Marsh area on the north. Below the community of Sprague River the ground water in the river valley slopes in the direction of surface flow at about the same gradient as the surface slope, about 5 feet per mile, for some distance. In the vicinity of Braymill the ground water gradient becomes steeper, and farther west the ground water merges with ground water moving southward from the Williamson River Hydrologic Unit.

The Lost River Hydrologic Unit in Oregon contains five separate or semi-separate valleys; Langell, Yonna, Swan Lake, Poe, and Klamath Valleys. Ground water in Yonna and Swan Lake Valleys clearly slopes toward Lost River, and enough information is available to indicate that Lost River is the base control for the remainder of these closely related valleys. In the upper parts of both Swan Lake and Yonna Valleys the ground water gradient in the main water body is about 20 feet per mile down the valley, although in Swan Lake Valley the gradient decreases in the central part of the valley. The slope of the perched water is toward the sides of the valley at a gentle gradient.

The main ground water bodies in Swan Lake and Yonna Valleys become a broad continuous body in the vicinity of Pine Flat. This body slopes southward to Lost River at a gradient of about 2 feet per mile.

The Upper Klamath Lake Hydrologic Unit includes the slopes on the eastern side of the Cascade Range, underlain principally by the High Cascade volcanics and some younger volcanics. These slopes receive infiltration in their upper parts, and at their bases a great many springs of various sizes discharge to the creeks and marshes. Seven-mile Creek, Mare's Egg Creek, Spring Creek, Threemile Creek, and Nannie Creek flow principally from discharge of ground water.

A limited amount of sampling and analysis indicates that most of the well water and spring water of the Klamath River Basin in Oregon is of excellent mineral quality and contains a relatively low amount of dissolved solids. Ground water of poor mineral quality has been found along certain fault zones, and in the alluvium near Lower Klamath Lake and Tule Lake where the salt content has been increased by evaporation.

Link River, Outlet of Upper Klamath Lake, showing intake to Klamath Project "A" Canal.

Klamath County Chamber of Commerce photograph

Dwinnell Reservoir on Shasta River

Department of Water Resources photograph

CHAPTER III

WATER UTILIZATION AND REQUIREMENTS

The nature and extent of water utilization and requirements in the Klamath River Basin at the present time and under probable conditions of ultimate development are considered in this chapter. In connection with the discussion, the following terms are used as defined below:

Water Utilization. This term is used in a broad sense to include employments of water by nature or man, either consumptive or nonconsumptive, as well as irrecoverable losses of water incidental, to such employment, and is synonymous with the term "water use."

Consumptive Use of Water. This refers to water consumed by vegetative growth in transpiration and building of plant tissue, and to water evaporated from adjacent soil, from water surfaces, and from foliage. It also refers to water consumed and evaporated by urban and nonvegetative types of land use.

Applied Water. The water delivered to a farmer's headgate in the case of irrigation use, or to an individual's meter in the case of urban use, or its equivalent. It does not include direct precipitation.

Water Requirement. The water needed to provide for all beneficial uses, and for unavoidable losses incidental to such uses.

Demands for Water. Those factors pertaining to specific rates, times and places of delivery of water, losses of water, quality of water, etc., imposed by the control, development, and use of water for beneficial purposes.

Effective Precipitation. That portion of the direct precipitation which is consumptively used and which does not run off or percolate to ground water.

Irrigation Efficiency. This refers to the ratio of consumptive use of applied water to the total amount of applied water for a specified area and a single use, expressed as a percentage.

Water Service Area Efficiency. This refers to the ratio of consumptive use of applied water in a given service area, with reuse of water where possible, to the gross amount of water delivered to the area, expressed as a percentage.

Present. This is used generally in reference to land use and water supply conditions prevailing during the period from 1953 to 1955.

Ultimate. This is used in reference to conditions after an unspecified, but long, period of years in the future, when land use and water supply development will be at a maximum and essentially stabilized.

Present Supplemental Water Requirement. This refers to the additional water needed to provide for all present beneficial consumptive uses of water and/or irrecoverable losses incidental to such use, over and above the safe yield of the present water supply development, with due allowance for irrigated agriculture to absorb an occasional deficiency in water supply in extremely dry seasons.

Probable Ultimate Supplemental Water Requirement. The difference between the present and probable ultimate water requirement, plus the present supplemental water requirement if such exists.

Present and probable ultimate water requirements in the Klamath River Basin were determined by application of appropriate unit consumptive use of water factors to the present and probable ultimate patterns of land use, with thorough consideration of the water service area efficiencies which are presently, or would ultimately be, achieved by operating agencies within each hydrographic subunit. In determining the present and probable ultimate water requirements, due consideration was given to present agricultural, urban, and industrial development and to those natural features of the Basin, such as climate, topography, and soils, as they affect the use and re-use of water.

Certain possible nonconsumptive requirements for water in the Klamath River Basin, such as those for hydroelectric power generation, flood control, conservation of fish and wildlife, recreation, etc., may be of varying significance in the final design of works to meet water requirements for the Basin. In most instances, the magnitude of such nonconsumptive requirements are relatively indeterminate, and dependent upon allocations made after consideration of public necessity or economics. Data which should be considered in allocating water for nonconsumptive requirements were investigated and are evaluated in this bulletin.

Water utilization and requirements are considered and evaluated in this chapter under the general headings "Present Water Supply Development," "Land Use," "Unit Use of Water," "Consumptive Use of Water," "Water Requirements," "Water Requirements of a Nonconsumptive Nature," "Demands for

Water," "Supplemental Water Requirements," and "Probable Future Change in Flow of Klamath River."

PRESENT WATER SUPPLY DEVELOPMENT

A number of public and private agencies, organized for the purpose of providing water for domestic and irrigation use, are found within the Klamath River Basin. With one exception, the principal agencies furnishing irrigation water have developed surface water as their main source of supply. The Butte Valley Irrigation District, however, utilizes ground water as well as water from surface sources for its supply. In addition to organized distribution agencies, private individuals have developed both ground water and surface water to a considerable extent throughout the Basin for domestic and stock uses and for irrigation.

Of the estimated 474,000 acres of land presently irrigated in the Klamath River Basin, some 219,200 acres are served by the principal water service agencies listed in Table 16, and the remaining 254,800 acres are served by small privately owned companies or by individual effort. In 1953, approximately 15,000 acres were supplied by pumping of ground water and the remainder by diversion of surface water.

Data pertaining to the principal water service agencies in the Klamath River Basin are given in Table 16. The service areas of these agencies are shown on Plate 2, entitled "Principal Water Service Agencies and Location of Hydroelectric Power Plants."

The largest water service agency within the Basin is the United States Bureau of Reclamation, serving the area within the Klamath Project. This project, encompassing approximately 196,000 acres of irrigated land in California and Oregon, is supplied by surface water diverted from Lost River and tributaries, Klamath River, and Upper Klamath Lake. From 1951 through 1954, an average of about 506,000 acre-feet per season was diverted into project canals from these sources. A number of organized districts, as well as individuals, contract with the Bureau of Reclamation for water supplies. Adjacent to the Klamath Project area, some 3,800 acres of land are presently being irrigated in Swan Lake and Yonna Valleys by individuals pumping ground water from wells.

The United States Bureau of Indian Affairs administers the Klamath Indian Reservation in Oregon. The reservation contains several small irrigation projects, under federal jurisdiction, which supply diverted surface water to an estimated 5,200 acres of land. A few individuals owning land within the reservation have drilled wells and are pumping ground water from shallow depths for irrigation. Along the Sprague River, within the reservation, several artesian wells produce good flows which are also used for irrigation.

In Butte Valley, in California, the organized agency providing irrigation water is the Butte Valley Irrigation District. This district presently includes approximately 4,700 acres in the southern end of the valley, of which about 4,000 acres are irrigated. The water supply for the district is obtained by surface diversions from Butte Creek, and by pumping from ground water into the district's canals. In 1953, the gross diversions amounted to 19,200 acre-feet, of which 7,800 acre-feet were from surface diversion, and 11,400 acre-feet from ground water pumping. In 1954, the gross diversions were 20,900 acre-feet, comprising 10,300 acre-feet from surface diversion and 10,600 acre-feet from ground water. Large quantities of the diverted water are lost by seepage from canals. The district has facilities for spreading surplus Butte Creek waters to aid in ground water recharge. The larger portion of Butte Valley is not in the district, and development of irrigated agriculture in this area is the result of individual effort. Large acreages have been placed under cultivation during the last several years, and are supplied with irrigation water by privately owned wells.

Four organized districts provide water service to approximately 10,000 acres of irrigated land in Shasta Valley. The Montague Water Conservation District, with a gross area of about 21,000 acres is the largest. The other districts, together with thin grass areas, are the Grenada Irrigation District, 2,000 acres; the Big Springs Irrigation District, 3,700 acres; and the Shasta River Water Users Association, 5,100 acres.

The Montague Water Conservation District obtains its water supply from Dwinnell Reservoir on the Shasta River. The Big Springs Irrigation District derives its water supply by pumping from a small spring-fed lake. The Shasta River Water Users Association and Grenada Irrigation District pump directly from the Shasta River. Some farmers in each district supplement available water supplies by pumping from the underlying ground water basin.

Within Shasta Valley approximately 24,000 acres lying outside the organized districts are served by individual diversions from various streams. Water rights on the Shasta River and its major tributaries have been adjudicated by Siskiyou County Superior Court, decision No. 7035, December 30, 1932, and distribution of water is supervised by a State watermaster. Additionally, 3,000 acres are irrigated by ground water pumping and by diversion from small streams which are not a part of the adjudicated stream system.

The major organized water service agency in Scott Valley, in California, is the Scott River Irrigation District. The district, utilizing the unregulated flow of the Scott River, diverts water from the river about 10 miles below Callahan. The water is carried, by means of ditch and flume, along the east side of the valley for a distance of 20 miles, serving a gross area of approximately 5,100 acres, of which about 3,500 acres are irrigated. Surface water supplies for irrigation are supplemented by pumping of ground water.

TABLE 16

PRINCIPAL WATER SERVICE AGENCIES IN THE KLAMATH RIVER BASIN

Name of agency	Source of water supply	Location of service area		Approximate area irrigated in 1953, in acres
		Hydrographic area	County	
United States Bureau of Reclamation	Lost River and tributaries, Upper Klamath Lake, and Klamath River	4C	Klamath Modoc Siskiyou	
Horsefly Irrigation District				7,950
Langell Valley Irrigation District				13,330
Pine Grove Irrigation District				870
Sunnyside Irrigation District				570
Shasta View Irrigation District				3,750
Malin Irrigation District				3,370
Enterprise Irrigation District				1,980
Klamath Drainage District				19,100
Van Brimmer Ditch Company				3,890
Lost River contracts				5,200
Tule Lake Sump contracts				1,190
Individual contracts				4,480
Klamath River contracts				3,490
Upper Klamath Lake contracts				7,880
Klamath River rentals				170
Lower Klamath Lake rentals				4,450
Miscellaneous rentals				4,320
Main Division (Klamath Irrigation District)				34,290
Tule Lake Division (Part 1)				34,330
Tule Lake Division (Part 2)				9,060
Tule Lake leases				18,090
Lower Klamath Lake leases				14,280
Subtotal				196,040
United States Bureau of Indian Affairs	Wood River and tributaries, Sprague River and tributaries, and Williamson River and tributaries	1, 2, 3A	Klamath, Lake	5,200
Butte Valley Irrigation District	Butte and Antelope Creeks, and wells	5A	Siskiyou	4,000
Montague Water Conservation District	Shasta River	6B, 6D	Siskiyou	5,000
Grenada Irrigation District	Shasta River	6C	Siskiyou	1,000
Shasta River Water Users Association	Shasta River	6B, 6C	Siskiyou	2,500
Big Springs Irrigation District	Big Springs	6D	Siskiyou	1,500
Scott Valley Irrigation District	Scott River	7A	Siskiyou	3,500

Most of the irrigated area in Scott Valley lies to the west of the river and is supplied by individual development. Surface runoff in small creeks is generally available to this portion of the valley throughout the summer and, in addition, satisfactory ground water supplies have been easily developed. The flow of Shackleford Creek, a tributary to the Scott River, has been adjudicated for use in Quartz Valley.

In the portion of the Klamath River drainage basin downstream from the Scott River, no organized water service agencies exist to supply irrigation water. With the exception of a small area in Hayfork Valley, a portion of the Hoopa Indian Reservation on the Trinity River, and small areas in the vicinity of Lewiston and Seiad Valley, only very minor cultivated valley areas are found in the lower Klamath River Basin. Seiad Creek, serving Seiad Valley, has been adjudicated and is under State watermaster supervision.

With the exception of the facilities for the Klamath Project and for the Montague Water Conservation District, the present works of organized water service agencies in the Klamath River Basin are limited to diversion installations, such as pumping plants and diversion weirs, and to necessary distribution systems. In the Klamath Project, regulatory storage has been developed in Clear Lake Reservoir, Gerber Reservoir, and Upper Klamath Lake. Regulation and diversion works are also provided at required points within the project area.

Clear Lake Reservoir has a storage capacity of more than 500,000 acre-feet. Irrigation diversions from this reservoir in 1951, 1952, and 1953 amounted to about 40,000 acre-feet each season, and in 1954 about 47,000 acre-feet. Seasonal water losses from the surface of this reservoir by evaporation are between 60,000 and 100,000 acre-feet. Gerber Reservoir has a storage capacity of 94,000 acre-feet. United States Bureau of Reclamation data shows that seasonal diversions from this reservoir were 44,400 acre-feet in 1951, 47,000 acre-feet in 1952, 44,000 acre-feet in 1953, and 50,000 acre-feet in 1954.

Upper Klamath Lake provides regulatory storage for both Klamath Project irrigation water and water used for hydroelectric power generation by The California Oregon Power Company. Its usable storage capacity is limited to 483,000 acre-feet between elevations of 4,137.0 and 4,143.3 feet, under terms of a

contract between the Bureau of Reclamation and the power company. During the four years from 1951 through 1954 the seasonal diversion of water from Upper Klamath Lake into the Klamath Project's "A" Canal averaged approximately 238,000 acre-feet, with a minimum diversion of 216,000 acre-feet in 1953 and a maximum of 256,000 acre-feet in 1954.

The Shasta River Dam, forming Dwinnell Reservoir, was built and is maintained by the Montague Water Conservation District, both for regulation of Shasta River runoff and for diversion of the conserved water into the district's distribution system. The dam was originally designed to impound 72,000 acre-feet of water, but due to excess leakage through the dam and concern for the stability of the structure, the water stage has been, in the past, maintained at or below an elevation providing an effective storage capacity of about 34,000 acre-feet. During 1954 and 1955, additional rock section was placed on the toe of the dam to increase stability of the structure. With this modification, the Department of Water Resources has approved the structure to store up to about 50,000 acre-feet of water. During the irrigation season from April to October of 1953, a total of 13,900 acre-feet of water were diverted into the district's main canal from this reservoir. Inflow to the reservoir is supplemented by a diversion of up to 15,000 acre-feet per season from Parks Creek, a tributary of the Shasta River.

The principal existing reservoirs within the Klamath River Basin, and the areas flooded at maximum water surface elevation are listed in Table 17.

The incorporated cities of Tulelake, Dorris, Yreka, Etna, Merrill, Malin, and Chiloquin have municipally owned water systems. All others, including Klamath Falls, Oregon, are served by privately owned water companies. Most municipal water supplies are obtained from wells. Individuals in the smaller communities, such as Beatty, Dairy, Bonanza, Fort Klamath, Callahan, and Keno, generally meet their water requirements from privately owned wells.

TABLE 17

PRINCIPAL EXISTING RESERVOIRS IN THE KLAMATH RIVER BASIN

Hydrographic unit and subunit		Reservoir	Maximum water surface area, in acres
Map reference number	Name		
3	Upper Klamath Lake	Upper Klamath Lake	98,400
4B	Clear Lake	Clear Lake	24,800
4B	Clear Lake	Gerber Reservoir	3,850
4C	Klamath Project	Tule Lake Sump	13,200
5A	Macdoel	Meiss Lake	3,800
6G	Upper Shasta	Dwinnell Reservoir	1,900
11A	Copco	Copco	1,000

The City of Yreka has experienced severe deficiencies in its water supply in recent years as a result of population increases. During 1958, the voters approved a bond issue that provided for construction of a 380 acre-foot reservoir on Greenhorn Creek to firm up present ground water supplies.

LAND USE

The first major step in evaluating water requirements of the Klamath River Basin was to determine the nature and extent of present land use, as related to use of water. This was accomplished by a field land use survey in 1952 and 1953. Similarly, a forecast of the probable nature and extent of ultimate land use was made, based on data from land classification surveys made in 1953. These surveys segregated lands within the Basin in relation to their suitability for irrigated agriculture or for other beneficial water-using purposes. Following land classification surveys made for the Northeastern Counties Investigation, the results of the earlier survey were modified in 1956 to conform to more recent standards. An exception to the general procedure was made in the case of future urban development, which was forecast on a population density basis.

Present and Probable Ultimate Populations

Cities and towns in the Klamath River Basin are small. Present densities of development vary to such an extent that it was considered impracticable to estimate urban water requirements on a land area basis. Rather, population estimates were utilized, in conjunction with estimates of per capita use of water, for this purpose. Urban populations were taken to include urban, urban fringe, and non-farm rural populations. Separate estimates of farm population were made, although water requirements for farmstead use were estimated on a land area basis. Estimates of present population were based upon data from the 1950 federal census, adjusted to 1953 conditions, and segregated in accordance with hydrographic units on the basis of available information from chambers of commerce, county registrars of voters, and other similar agencies.

The ultimate urban population of the Basin was forecast as the number of people that could be supported by the anticipated ultimate development of timber, agriculture, and other industries within the Basin. A relationship between irrigated lands and urban population depending upon agriculture was determined from studies of several strictly agricultural areas in California, and by correlation of these areas with the Klamath River Basin through census data. Since the urban population is also dependent upon the timber industry, an additional population projection, based on estimates of ultimate sustained yield of timber products, and the number of persons presently employed in and supported by the industry, was

Intensively developed agricultural land within the Klamath Project

Eastman's Studio, Susanville, photograph

Potato harvest in the Klamath Project

Eastman's Studio, Susanville, photograph

TABLE 18

ESTIMATED PRESENT AND PROBABLE ULTIMATE POPULATIONS WITHIN HYDROGRAPHIC UNITS IN THE KLAMATH RIVER BASIN

Hydrographic unit or subunit		Present (1953) population			Probable ultimate population		
Reference number	Name	Urban	Farm	Total	Urban	Farm	Total
1	Williamson River	1,200	300	1,500	3,100	900	4,000
2	Sprague River	1,400	350	1,750	3,600	1,100	4,700
3	Upper Klamath Lake						
3A	Wood River	600	400	1,000	2,800	1,300	4,100
3B	Klamath Lake	[a]	100	100	800	400	1,200
	Subtotals	600	500	1,100	3,600	1,700	5,300
4	Lost River						
4A	Swan Lake	[a]	100	100	1,200	700	1,900
4B	Clear Lake	[a]	100	100	1,100	500	1,600
4C	Klamath Project	35,000	4,200	39,200	40,600	6,800	47,400
4D	Lava Beds	1,000	[a]	1,000	600	100	700
4E	Oklahoma	[a]	200	200	1,100	1,000	2,100
	Subtotals	36,000	4,600	40,600	44,600	9,100	53,700
5	Butte Valley						
5A	Macdoel	1,400	400	1,800	4,400	1,300	5,700
5B	Butte Creek	600	100	700	1,700	700	2,400
5C	Red Rock	[a]	50	50	400	200	600
	Subtotals	2,000	550	2,550	6,500	2,200	8,700
6	Shasta Valley						
6A	Yreka	5,500	[a]	5,500	13,200	100	13,300
6B	Little Shasta	700	350	1,050	3,200	1,200	4,400
6C	Gazelle-Grenada	600	350	950	2,400	1,000	3,400
6D	Big Springs-Juniper	[a]	150	150	1,100	500	1,600
6E	Grass Lake	50	0	50	200	[a]	200
6F	Parks Creek	[a]	50	50	600	100	700
6G	Upper Shasta River	4,250	50	4,300	18,000	300	18,300
	Subtotals	11,100	950	12,050	38,700	3,200	41,900
7	Scott Valley						
7A	East Side	500	250	750	4,100	500	4,600
7B	Moffett Creek	[a]	50	50	500	100	600
7C	Quartz Valley	100	150	250	1,000	200	1,200
7D	West Side	600	400	1,000	2,400	600	3,000
7E	Callahan	300	100	400	1,000	100	1,100
	Subtotals	1,500	950	2,450	9,000	1,500	10,500
8	Salmon River						
8A	Wooley Creek	[a]	0	[a]	200	[a]	200
8B	North Fork of Salmon	400	0	400	1,600	[a]	1,600
8C	South Fork of Salmon	150	0	150	1,600	[a]	1,600
	Subtotals	550	0	550	3,400	[a]	3,400
9	Upper Trinity River	700	350	1,050	3,700	100	3,800
10	Lower Trinity River	4,900	100	5,000	11,900	300	12,200
11	Klamath River						
11A	Copco	100	50	150	300	200	500
11B	Hornbrook	900	100	1,000	300	100	400
11C	Ager	50	50	100	400	300	700
11D	Happy Camp	3,100	100	3,200	19,100	300	19,400
11E	Mouth of Klamath	1,050	50	1,100	24,200	200	24,400
	Subtotals	5,200	350	5,550	44,300	1,100	45,400
12	South Fork of Trinity River						
12A	Hyampom	200	50	250	2,200	100	2,300
12B	Hayfork	800	200	1,000	4,000	200	4,200
	Subtotals	1,000	250	1,250	6,200	300	6,500
	APPROXIMATE TOTALS, KLAMATH RIVER BASIN	66,000	9,000	75,000	179,000	21,000	200,000

[a] Population negligible.

TABLE 19

ESTIMATED PRESENT AND PROBABLE ULTIMATE POPULATIONS WITHIN COUNTIES IN THE KLAMATH RIVER BASIN

State and county	Present (1953) population			Probable ultimate population		
	Urban	Farm	Total	Urban	Farm	Total
Oregon						
Lake	[a]	50	50	400	300	700
Klamath	37,500	5,350	42,850	50,000	10,400	60,400
Jackson	[a]	[a]	[a]	[a]	100	100
Josephine	0	0	0	0	0	0
Subtotals	37,500	5,400	42,900	50,400	10,800	61,200
California						
Modoc	1,400	300	1,700	1,600	600	2,200
Siskiyou	19,600	2,750	22,300	80,500	9,300	89,800
Trinity	5,200	700	5,900	19,300	500	19,800
Humboldt	1,400	50	2,550	6,800	200	7,000
Del Norte	1,050	50	1,100	20,000	100	20,100
Subtotals	28,650	3,850	32,500	128,200	10,700	138,900
APPROXIMATE TOTALS, KLAMATH RIVER BASIN	66,000	9,000	75,000	179,000	21,000	200,000

[a] Population negligible.

made. Most of these data were furnished by the United States Forest Service and by lumber and wood product companies.

Estimates of present and probable ultimate population in the Klamath River Basin, within hydrographic units and counties, respectively, are presented in Tables 18 and 19.

Present Water Service Areas

Information concerning land use in the Klamath River Basin that was available at the inception of this investigation, particularly with regard to irrigated acreages and crops, was incomplete and not considered sufficiently accurate to form a basis for estimates of water requirements. Consequently, a field survey was conducted during 1953 for the purpose of mapping irrigated and other lands requiring water service in accordance with use, crop type, and source of water supply.

Throughout the Basin, with minor exceptions, the most recent available aerial photographs, at a scale of 1 to 20,000, were used in mapping. The areas devoted to various uses and crop types were delineated on the photographs, and transferred to base maps at a scale of 1 to 24,000, from which the acreage determinations were made. Data as to the extent of irrigated lands and other water service areas in the Klamath Indian Reservation in Oregon were provided by the Bureau of Reclamation, based on information from the Bureau of Indian Affairs and supplemented by results of a reconnaissance survey. However, the locations of irrigated lands in the reservation were not available for use in preparing the maps accompanying this bulletin.

Determination of areas devoted to various uses and crops was made in terms of the gross included areas of water service. The gross areas were reduced by estimated percentages of included non-productive land, such as county and state highways, farm access roads, etc., in order to determine net (or actual) water service areas. The percentage factors used were based on results of a detailed sampling survey in a representative portion of the Klamath Project, and on experience in other similar areas in California.

The present land use pattern in the Klamath River Basin consists of irrigated lands, urban lands, miscellaneous water service areas, and swamp and marsh lands. Irrigated lands were taken to include all agricultural lands dependent upon surface application of water, as well as those agricultural lands utilizing water from a high water table or from winter flooding. Thus sub-irrigated and pre-irrigated lands were included, for each crop, with the surface irrigated lands.

Irrigated pasture lands were subdivided into three groups because of differences which were found to exist in water requirement caused by the cropping practices. Improved pasture consists of lands with improved irrigation facilities, cropped to selected grains, grasses, and legumes. Marginal pasture consists primarily of native and volunteer grasses, irrigated either by surface application or sub-irrigation. Meadow pasture generally consists of unimproved land with native grasses of a poorer type, such as rush grass and wire grass, which is sub-irrigated from a high water table. Meadow pasture often is found in areas with impaired drainage and resultant alkaline soil conditions. Since determination of water requirements was the primary objective, no distinction was made between pastures used for forage and those cut for hay; between small grains harvested and cut for hay; or between clover used for seed production and that used for pasture.

TABLE 20

PRESENT WATER SERVICE AREAS (1953 to 1955) WITHIN HYDROGRAPHIC UNITS IN THE KLAMATH RIVER BASIN

(In acres)

Hydrographic unit and subunit		Type of land use													
		Irrigated lands													
				Pasture											
Reference number	Name	Alfalfa	Clover	Improved	Marginal	Meadow	Hay and grain	Orchard	Truck	Potatoes	Total net irrigated area	Urban lands	Miscellaneous	Swamp and marsh lands	Principal reservoirs and lakes
1	Williamson River	0	0	0	10,200	50,770	0	0	0	0	60,970	160	240	15,000	0
2	Sprague River	0	410	6,180	2,660	21,910	5,840	0	0	0	37,000	180	320	7,000	0
3	Upper Klamath Lake														
3A	Wood River	380	0	32,240	1,930	0	6,180	0	0	0	40,730	90	920	20,740	3,000
3B	Klamath Lake	420	0	5,640	0	1,650	2,930	0	0	330	10,970	0	230	9,590	65,000
	Subtotals	800	0	37,880	1,930	1,650	9,110	0	0	330	51,700	90	1,150	30,330	68,000
4	Lost River														
4A	Swan Lake	360	0	1,240	0	0	5,680	0	0	40	7,320	0	150	0	0
4B	Clear Lake	0	10	1,350	1,060	10,940	150	0	0	0	13,510	0	280	1,160	26,000
4C	Klamath Project	29,050	11,760	19,520	12,070	600	106,680	20	690	22,920	203,310	3,500	4,290	4,670	11,100
4D	Lava Beds	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4E	Oklahoma	240	0	610	5,280	1,250	510	0	0	10	7,900	0	170	1,330	3,200
	Subtotals	29,650	11,770	22,720	18,410	12,790	113,020	20	690	22,970	232,040	3,500	4,890	7,160	40,300
5	Butte Valley														
5A	Macdoel	1,730	810	860	960	290	3,310	10	10	2,460	10,440	660	220	110	2,800
5B	Butte Creek	0	0	150	1,140	2,350	0	0	10	0	3,650	60	80	0	200
5C	Red Rock	0	0	0	0	0	0	0	0	0	0	0	0	0	*
	Subtotals	1,730	810	1,010	2,100	2,640	3,310	10	20	2,460	14,090	720	300	110	3,000
6	Shasta Valley														
6A	Yreka	210	0	40	0	20	0	0	0	0	270	610	70	0	*
6B	Little Shasta	5,920	10	2,990	4,250	360	480	10	0	0	14,020	100	500	0	100
6C	Gazelle-Grenada	3,200	0	2,990	3,020	1,120	300	0	10	0	10,640	110	220	0	200
6D	Big Springs-Juniper	900	0	2,160	80	1,050	190	0	0	10	4,390	0	90	0	100
6E	Grass Lake	0	0	0	0	310	0	0	0	0	310	0	10	1,310	0
6F	Parks Creek	160	0	2,760	260	400	80	0	0	0	3,660	0	80	0	0
6G	Upper Shasta	260	0	2,950	60	470	220	0	0	0	3,960	630	110	0	1,600
	Subtotals	10,650	10	13,890	7,670	3,730	1,270	10	10	10	37,250	1,450	1,080	1,310	2,000
7	Scott Valley														
7A	East Side	1,780	40	2,280	240	960	1,840	0	0	0	7,140	30	150	60	0
7B	Moffett Creek	400	0	420	50	170	210	0	0	0	1,250	100	30	0	0
7C	Quartz Valley	420	0	960	750	1,250	540	0	0	0	3,920	0	80	0	0
7D	West Side	1,340	130	4,500	490	5,320	4,210	10	0	0	16,450	30	350	60	0
7E	Callahan	220	0	1,130	80	510	150	0	0	0	2,090	0	40	0	0
	Subtotals	4,160	170	9,290	2,060	8,210	6,950	10	0	0	30,850	160	650	120	0

8	Salmon River														
8A	Wooley Creek	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8B	North Fork of Salmon	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8C	South Fork of Salmon	10	0	90	0	0	0	0	0	0	100	0	0	0	0
	Subtotals	10	0	90	0	0	0	0	0	0	100	0	0	0	0
9	Upper Trinity River	0	0	1,890	0	0	0	0	0	0	1,890	400	40	0	13,100
10	Lower Trinity River	140	20	340	0	0	0	0	10	0	510	100	10	0	0
11	Klamath River														
11A	Copco	20	0	140	430	120	40	0	0	0	750	0	20	10	800
11B	Hornbrook	460	0	540	660	40	300	0	0	0	2,000	140	150	0	0
11C	Ager	290	0	190	910	0	380	0	0	0	1,770	0	40	0	•
11D	Happy Camp	100	40	780	200	300	190	50	10	0	1,670	70	30	0	0
11E	Mouth of Klamath	0	0	130	60	200	0	0	0	0	390	30	10	0	0
	Subtotals	870	40	1,780	2,260	660	910	50	10	0	6,580	240	250	10	800
12	South Fork of Trinity River														
12A	Hyampom	40	0	280	0	0	20	0	0	0	340	0	10	0	0
12B	Hayfork	30	20	70	580	0	0	0	0	0	700	470	0	0	0
	Subtotals	70	20	350	580	0	20	0	0	0	1,040	470	10	0	0
	APPROXIMATE TOTALS, KLAMATH RIVER BASIN	48,100	13,300	95,400	47,900	102,400	140,400	100	700	25,800	474,000	7,500	8,900	61,000	127,200

Urban lands were taken to include the developed area of cities and towns within the Basin, without consideration to municipal boundaries. Miscellaneous water service areas include parks, golf courses, cemeteries, and industrial sites, where such uses do not occur within urban boundaries. Additionally, miscellaneous water service areas include the farmstead areas, estimated as a percentage of the irrigated land. Swamp and marsh lands comprise those areas that are, for most of the year, too wet to provide agricultural value. These are, however, consumers of water and often make a heavy demand on available water supplies. For this reason they were included in the compilation of present water service areas.

The areal extent of irrigated and urban lands, miscellaneous water service areas, and swamp and marsh lands in the Klamath River Basin during 1953, except within Klamath Indian Reservation, is delineated on Plate 15, entitled "Present and Probable Ultimate Water Service Areas." This plate comprises 14 sectional maps and an index.

Table 20 summarizes, by hydrographic unit and subunit, the nature and extent of lands presently irrigated, utilized for urban purposes, classified as miscellaneous water service areas, or consisting of swamp and marsh lands, and principal reservoirs and lakes. Table 21 summarizes these data for the portions of counties within the Basin in Oregon and California.

The net irrigated area, subdivided into that irrigated by surface application and that by sub-irrigation, is tabulated in Table 22. In the analysis of the hydrology of the Basin, and the evaluation of water requirements, consideration was given to this difference in irrigation practice. Table 23 presents the same data by counties.

Probable Ultimate Pattern of Land Use

The present water requirement for irrigated agriculture in the Klamath River Basin is predominant and greatly in excess of other needs, such as urban and industrial uses. Although the magnitude of the other water requirements may increase significantly in the future, it is probable that the relative importance of the irrigation requirement will be maintained even under ultimate conditions of development. During this investigation, therefore, considerable emphasis was placed upon the classification of potentially irrigable lands and upon the forecast of the probable ultimate crop pattern.

During 1953, a field survey was conducted of the Klamath River Basin, exclusive of the Klamath Indian Reservation, for the purpose of locating, mapping and classifying those lands suitable for ultimate irrigation development. During the survey, information was compiled to assist in forecasting the probable crop pattern that would result with such development. The potentially irrigable lands were subdivided into various crop adaptability classes according to soil types, soil profiles and the physical characteristics of the land. The crop adaptability classification was used to provide a direct approach to estimating the ultimate crop pattern.

Within the Indian reservation, applicable land classifications of the Bureau of Reclamation and Bureau of Indian Affairs were utilized. These were generally based on a reconnaissance survey, and the available data pertained to total irrigable areas, unsegregated with regard to crop adaptability.

In 1956, in connection with the Northeastern Counties Investigation, the land classification was reviewed and modified in accordance with the revised and improved standards used in that investigation. The principal modification was the addition of a class for irrigable lands that are presently forested, or irrigable lands adaptable to forest production. These lands meet the requirements for irrigable land but are, because of climatic conditions and physiographic position, better suited for timber production or some type of forest management program, than for irrigated agriculture. Lands in the Klamath River Basin in California within this category were accordingly reclassified, and the previously published data pertaining to irrigable lands were revised.

The land classification survey considered such physical characteristics as topography, soil depth, soil texture, saline or alkaline conditions, high water table conditions, and the presence of rock. Consideration was also given to climatic conditions, ease of irrigation, and present agricultural practices. Economic factors relating to production and marketing, variable among given areas and subject to considerable fluctuation over a period of years, were not considered. The position of the land as related to a possible source of water supply, and the availability of adequate water supplies, were not factors influencing the land classification.

As has been stated, climatic conditions vary widely throughout the Klamath River Basin. The length of the average frost free period is from 100 to 150 days in Scott, Shasta, and Butte Valleys, and in the southern portion of Lost River drainage area. In the lower reaches of the Klamath River Basin the average frost free period extends from 150 to 225 days. The shorter periods generally limit adaptable crops to pasture and alfalfa, while longer periods permit the production of these crops as well as grains, truck, potatoes, and to a more limited extent, orchards and miscellaneous field crops. Reductions in yield may occur in years with unseasonable frosts.

Table 24 comprises a description of each crop adaptability class, and the classification standards presently utilized by the Department of Water Resources.

The areas mapped as irrigable are shown in yellow on Plate 15. The gross irrigable area of 1,070,000 acres also includes the present water service area de-

TABLE 21

PRESENT WATER SERVICE AREAS (1953 to 1955) WITHIN COUNTIES IN THE KLAMATH RIVER BASIN

(In acres)

State and county	Type of land use													
	Irrigated lands													
			Pasture											
	Alfalfa	Clover	Improved	Marginal	Meadow	Hay and grain	Orchard	Truck	Potatoes	Total net irrigated area	Urban lands	Miscel-laneous	Swamp and marsh land	Principal reservoirs and lakes
Oregon														
Lake	0	0	1,410	0	17,180	0	0	0	0	18,590	0	80	7,400	0
Klamath	25,320	8,290	63,820	27,550	62,050	74,080	20	90	11,570	272,790	3,680	4,610	49,510	71,800
Jackson	10	0	0	110	0	20	0	0	0	140	0	0	0	0
Josephine	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotals	25,330	8,290	65,230	27,660	79,230	74,100	20	90	11,570	291,520	3,680	4,690	56,910	71,800
California														
Modoc	3,340	3,110	740	290	6,760	20,360	0	280	8,350	43,230	0	910	70	22,200
Siskiyou	19,200	1,810	26,710	19,280	16,170	45,950	50	350	5,850	135,370	2,760	3,230	4,060	20,100
Trinity	150	20	2,540	580	0	20	0	0	0	3,310	960	70	0	13,100
Humboldt	60	20	70	0	0	0	30	20	0	200	30	0	0	0
Del Norte	0	0	130	60	200	0	0	0	0	390	40	40	0	0
Subtotals	22,750	4,960	30,190	20,200	23,130	66,340	80	650	14,200	182,500	3,790	4,250	4,130	55,400
APPROXIMATE TOTALS, KLAMATH RIVER BASIN	48,100	13,300	95,400	47,900	102,400	140,400	100	700	25,800	474,000	7,500	8,900	61,000	127,200

TABLE 22

PRESENT AREAS OF SURFACE IRRIGATED AND SUB-IRRIGATED LANDS WITHIN HYDROGRAPHIC UNITS IN THE KLAMATH RIVER BASIN

(In acres)

Hydrographic unit and subunit		Surface irrigated lands	Sub-irrigated lands	Net irrigated area
Reference number	Name			
1	Williamson River	10,200	50,770	60,970
2	Sprague River	15,090	21,910	37,000
3	Upper Klamath Lake			
3A	Wood River	32,690	8,040	40,730
3B	Klamath Lake	9,320	1,650	10,970
	Subtotals	42,010	9,690	51,700
4	Lost River			
4A	Swan Lake	7,320	0	7,320
4B	Clear Lake	2,570	10,940	13,510
4C	Klamath Project	202,690	620	203,310
4D	Lava Beds	0	0	0
4E	Oklahoma	3,460	4,440	7,900
	Subtotals	216,040	16,000	232,040
5	Butte Valley			
5A	Macdoel	9,440	1,000	10,440
5B	Butte Creek	1,010	2,640	3,650
5C	Red Rock	0	0	0
	Subtotals	10,450	3,640	14,090
6	Shasta Valley			
6A	Yreka	250	20	270
6B	Little Shasta	10,830	3,190	14,020
6C	Gazelle-Grenada	6,270	4,370	10,640
6D	Big Springs-Juniper	3,280	1,110	4,390
6E	Grass Lake	0	310	310
6F	Parks Creek	1,450	2,210	3,660
6G	Upper Shasta	1,890	2,070	3,960
	Subtotals	23,970	13,280	37,250
7	Scott Valley			
7A	East Side	4,430	2,710	7,140
7B	Moffett Creek	560	690	1,250
7C	Quartz Valley	2,220	1,700	3,920
7D	West Side	5,990	10,460	16,450
7E	Callahan	1,540	550	2,090
	Subtotals	14,740	16,110	30,850
8	Salmon River			
8A	Wooley Creek	0	0	0
8B	North Fork of Salmon	0	0	0
8C	South Fork of Salmon	100	0	100
	Subtotals	100	0	100
9	Upper Trinity River	1,890	0	1,890
10	Lower Trinity River	510	0	510
11	Klamath River			
11A	Copco	600	150	750
11B	Hornbrook	1,950	50	2,000
11C	Ager	1,710	60	1,770
11D	Happy Camp	1,360	310	1,670
11E	Mouth of Klamath	180	210	390
	Subtotals	5,800	780	6,580
12	South Fork of Trinity River			
12A	Hyampom	340	0	340
12B	Hayfork	700	0	700
	Subtotals	1,040	0	1,040
	APPROXIMATE TOTALS KLAMATH RIVER BASIN	342,000	132,000	474,000

TABLE 23

PRESENT AREAS OF SURFACE IRRIGATED AND SUB-IRRIGATED LANDS WITHIN COUNTIES IN THE KLAMATH RIVER BASIN

(In acres)

State and county	Surface irrigated lands	Sub-irrigated lands	Net irrigated area
Oregon			
Lake	1,410	17,180	18,590
Klamath	202,710	70,080	272,790
Jackson	140	0	140
Josephine	0	0	0
Subtotals	204,260	87,260	291,520
California			
Modoc	36,460	6,770	43,230
Siskiyou	97,430	37,940	135,370
Trinity	3,310	0	3,310
Humboldt	200	0	200
Del Norte	180	210	390
Subtotals	137,580	44,920	182,500
APPROXIMATE TOTALS, KLAMATH RIVER BASIN	342,000	132,000	474,000

lineated in green. Approximately 865,000 acres, or some 81 percent of the potential irrigable lands in the Klamath River Basin, are found in the four principal valleys, Scott, Shasta, Butte, and Lost River, and around the marshes of the northern portion of the Basin. The small valleys and noncontiguous stringers of relatively flat land along streams in the remainder of the Basin include about 6,000 acres of irrigable land, less than one percent of the total. Irrigable hill lands comprise the remaining 18 percent of potentially irrigable lands.

The majority of the valley floor soils are of fair to good agricultural quality and will produce all climatically adapted crops. Topography is generally smooth and level in Lost River and Butte Valleys,

TABLE 24

CROP ADAPTABILITY CLASSIFICATION STANDARDS

Land Class — *Characteristics*

Irrigable Lands

V. Smooth lying lands with slopes up to 6 per cent in general gradient, in reasonably large-sized bodies sloping in the same plane; or slightly undulating lands which are less than 4 per cent in general gradient. The soils have medium to deep effective root zones, are permeable throughout, and free of salinity, alkalinity, rock or other conditions limiting crop adaptability of the land. These lands are suitable for all climatically adapted crops.

H. Gently sloping and undulating lands with slopes up to a maximum of 20 per cent for smooth, large-sized bodies sloping in the same plane; and grading down to a maximum slope of less than 12 per cent for undulating lands. The soils are permeable, with medium to deep effective root zones, and are suitable for the production of all climatically adapted crops. The only limitation is that imposed by topographic conditions, which affect the ease of irrigation and the amount of these lands that may ultimately be developed for irrigation.

Ht. Steeply sloping and rolling lands with slopes up to a maximum of 30 per cent for smooth, large-sized bodies sloping in the same plane; and grading down to a maximum slope of less than 20 per cent for lands with rougher topography. The soils are permeable, with medium to deep effective root zones, and are suitable for the production of all climatically adapted crops. The only limitation is that imposed by topographic conditions, which affect the ease of irrigation and the amount of these lands that may ultimately be developed for irrigation.

The above classes may be further modified, as conditions warrant, by use of one or more of the following symbols, such as Vp or Hpr.

p Indicates shallow depth of the effective root zone, which limits use of these lands to shallow-rooted crops.

r Indicates the presence of rock on the surface or within the plow zone in sufficient quantity to prevent use of the land for cultivated crops.

w Indicates the presence of a high-water table, which in effect limits the present crop adaptability of these lands to pasture crops. Drainage and a change in irrigation practice would be required to affect the crop adaptability.

s Indicates the presence of an excess of soluble salts or exchangeable sodium in slight amounts, which limits the present adaptability of these lands to crops tolerant to such conditions. The presence of salts within the soil generally indicates poor drainage and a medium to high-water table. Reclamation of these lands will involve drainage and the application of small amounts of amendments and some additional water over and above crop requirements in order to leach out the harmful salts.

Irrigable Forest Lands

F Presently forested lands, or lands subject to forest management, which meet the requirements for irrigable land but which, because of climatic conditions and physiographic position, are better suited for timber production or some type of forest management program rather than for irrigated agriculture.

with more microrelief apparent in Scott and Shasta Valleys. In general, the topography of the valley lands is such as to permit most types of irrigation practice. However, limiting soil depths restrict crops to the shallower rooted varieties in portions of the Basin.

Soil textures vary from medium to heavy in Scott and Shasta Valleys and along the tributary streams of the southern portion of the Basin. In Butte Valley, and in portions of Lost River Valley, the soil textures are medium to light. Soils of the northern portion of the Basin, drained by the Williamson, Sprague, and Wood Rivers, contain admixtures of pumice, giving them a distinctive texture not commonly found in irrigable lands. These soils have a very low water-holding capacity, and produce pasture crops only where the geologic structure is such that a high water table condition is maintained.

Under the adopted classification standards, irrigable hill lands include those which fail to meet the requirements for valley floor lands in regard to topography, but which are suitable for the production of certain crops with special irrigation practices. Since these lands are characterized by steep or rolling topography, care must be exercised in the type of irrigation practice. The best of the irrigable hill lands have adequate soil depth and are suitable for all climatically adapted crops. These lands comprise about 127,000 acres, or some 12 per cent of the total potentially irrigable area in the Klamath River Basin. The remainder of the irrigable hill land, totaling some 71,000 acres or about 6 per cent of the potentially irrigable area, is generally of good quality but soil depths, rock, and excessive slopes limit production to irrigated pasture.

Results of the classification in terms of gross area of potentially irrigable lands in the Klamath River Basin are presented in Table 25, segregated by hydrographic units and subunits, and in Table 26, segregated by counties.

By utilizing data from the land classification and the survey of present land use, and supplemental information from all available sources regarding probable future trends of development, a pattern of probable ultimate land use was forecast for the Klamath River Basin, as related to its requirements for water. This land use pattern included the estimate of ultimate irrigated lands as well as forecasts of all other anticipated ultimate water service areas.

As results of the land classification survey were in terms of gross acreages, these areas were reduced, by the application of appropriate percentage factors, to average net acreages assumed to be irrigated in any one season under ultimate conditions. The factors account for the effects of size and shape of the parcels of irrigable lands, inclusion of small areas of non-irrigable lands within those classified as potentially irrigable, productive capacity of the lands and probable crop rotation, ease of irrigation development, and inclusion of roads, highways, and other non-agricultural land uses. The factors were generally based on measurements previously made in intensively developed irrigated areas of the State, and on knowledge of the characteristics of the lands under consideration. Possible water developments were not considered in establishing the ultimate pattern of land use and ultimate water requirements.

The estimated ultimate crop pattern, reflecting the classification of lands, present experience in producing crops, climatic conditions, and indicated trends in irrigated agriculture, was then determined. In general, the intensive type of agriculture, based mainly on the production of grain, potatoes, seed crops, and pasture, now prevalent in the Klamath Project and in portions of Butte Valley was assumed to prevail for most irrigable valley floor lands in those areas. The remainder of the Klamath River Basin is well suited to livestock production, with pasture and hay the predominant irrigated valley floor crops. Extensive grazing lands surround the valley floor lands, and many ranches irrigate pasture and hay to supplement feed from the grazing lands, creating a balanced development. Following the present trend, pasture crops were considered to comprise the largest single crop acreage in the ultimate pattern of land use.

TABLE 25

CLASSIFICATION OF POTENTIALLY IRRIGABLE LANDS WITHIN HYDROGRAPHIC UNITS IN THE KLAMATH RIVER BASIN

(In acres)

Hydrographic unit and subunit:		Irrigable land class															
Reference number	Name	V	Vp	Vr	Vpr	Vw	Vs	H	Hp	Hr	Hpr	Ht	Htp	Htr	Htpr	*Un-segre-gated	Gross irri-gable area
1	Williamson River	0	0	0	0	0	0	0	0	0	0	0	0	0	0	74,600	74,600
2	Sprague River	8,920	1,250	70	840	21,580	0	990	7,830	10	3,370	70	210	10	100	64,700	109,950
3	Upper Klamath Lake																
3A	Wood River	39,290	640	910	900	13,920	0	7,000	0	0	0	0	0	0	0	28,700	91,360
3B	Klamath Lake	12,940	1,390	20	0	2,170	250	4,310	90	0	0	130	0	0	0	0	21,300
	Subtotals	52,230	2,030	930	900	16,090	250	11,310	90	0	0	130	0	0	0	28,700	112,660
4	Lost River																
4A	Swan Lake	27,980	0	0	0	0	0	3,580	0	140	0	70	0	0	0	0	31,770
4B	Clear Lake	8,060	0	6,070	4,060	13,310	0	1,190	0	500	0	0	0	0	0	0	33,190
4C	Klamath Project	229,300	220	1,440	1,760	2,090	17,650	45,420	7,260	5,020	190	2,950	2,130	350	0	0	315,780
4D	Lava Beds	1,290	0	160	0	0	0	3,250	0	110	0	0	0	0	0	0	4,810
4E	Oklahoma	7,020	720	40	0	6,060	7,410	8,180	340	230	100	710	0	0	0	0	30,810
	Subtotals	273,650	940	7,710	5,820	21,460	25,060	61,620	7,600	6,000	290	3,730	2,130	350	0	0	416,360
5	Butte Valley																
5A	Macdoel	51,640	40	2,200	0	960	6,230	3,540	200	310	0	1,070	0	0	0	0	66,190
5B	Butte Creek	13,690	210	930	0	3,570	20	840	170	0	0	0	0	0	0	0	19,430
5C	Red Rock	5,830	2,590	420	100	1,880	0	0	80	190	1,210	260	0	0	0	0	12,560
	Subtotals	71,160	2,840	3,550	100	6,410	6,250	4,380	450	500	1,210	1,330	0	0	0	0	98,180
6	Shasta Valley																
6A	Yreka	2,590	0	0	0	0	0	2,500	1,050	0	70	120	520	0	0	0	6,850
6B	Little Shasta	24,850	2,140	4,350	2,230	2,290	2,850	3,120	6,420	1,000	1,050	120	120	0	0	0	50,540
6C	Gazelle-Grenada	16,240	0	6,000	60	4,210	3,110	5,720	840	1,540	0	410	0	0	0	0	38,130
6D	Big Springs-Juniper	9,920	0	6,390	0	1,110	120	850	70	670	0	270	0	0	0	0	19,400
6E	Grass Lake	1,250	0	0	0	0	30	400	0	0	0	0	0	0	0	0	1,680
6F	Parks Creek	2,030	0	2,300	0	2,110	1,600	180	0	1,710	0	0	120	0	0	0	10,050
6G	Upper Shasta	5,230	0	1,560	0	1,970	160	3,950	60	800	0	240	0	0	0	0	13,970
	Subtotals	62,110	2,140	20,600	2,290	11,690	7,870	16,720	8,440	5,720	1,120	1,160	760	0	0	0	140,620
7	Scott Valley																
7A	East Side	12,290	0	40	0	630	0	5,000	350	70	0	320	300	0	0	0	19,000
7B	Moffett Creek	2,990	0	0	0	0	0	1,630	0	0	0	250	20	0	0	0	4,890
7C	Quartz Valley	5,450	0	1,820	0	1,480	0	630	0	0	0	0	0	0	0	0	9,380
7D	West Side	13,060	0	3,020	0	5,600	0	2,710	160	0	0	450	150	0	0	0	25,150
7E	Callahan	1,960	0	90	0	170	0	1,510	550	0	20	780	1,190	0	0	0	6,270
	Subtotals	35,750	0	4,970	0	7,880	0	11,480	1,060	70	20	1,800	1,660	0	0	0	64,690
8	Salmon River																
8A	Wooley Creek	0	0	0	0	0	0	90	0	0	0	0	0	0	0	0	90
8B	North Fork of Salmon	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	30
8C	South Fork of Salmon	0	0	0	0	0	0	280	0	0	0	150	0	0	0	0	430
	Subtotals	0	0	0	0	0	0	400	0	0	0	150	0	0	0	0	550

9	Upper Trinity River	720	0	740	0	0	0	610	0	200	0	0	0	0	0	0	2,270
10	Lower Trinity River	1,630	0	170	0	0	0	4,630	0	40	0	660	0	0	0	0	7,130
11	Klamath River																
11A	Copco	1,430	80	210	0	430	0	2,810	200	40	0	150	0	0	0	0	5,350
11B	Hornbrook	1,450	0	40	0	10	0	820	1,520	80	200	320	770	60	0	0	5,270
11C	Ager	3,140	90	20	0	0	0	2,650	4,090	0	260	300	2,600	0	160	0	13,310
11D	Happy Camp	1,700	0	210	0	0	0	3,710	0	100	0	1,410	0	0	0	0	7,130
11E	Mouth of Klamath	2,430	0	0	0	370	0	290	0	0	0	0	0	0	0	0	3,090
	Subtotals	10,150	170	480	0	810	0	10,280	5,810	220	460	2,180	3,370	60	160	0	34,150
12	South Fork of Trinity River																
12A	Hyampom	300	0	220	0	0	0	840	0	0	0	110	0	0	0	0	1,470
12B	Hayfork	1,960	0	150	0	0	0	3,720	100	0	0	220	0	0	0	0	6,150
	Subtotals	2,260	0	370	0	0	0	4,560	100	0	0	330	0	0	0	0	7,620
	APPROXIMATE TOTALS, KLAMATH RIVER BASIN	518,600	9,400	39,600	10,000	85,900	39,400	127,000	31,400	12,800	6,500	11,500	8,100	400	300	168,000	1,070,000

[a] Unsegregated land classified as irrigable by United States Bureau of Reclamation.

In the ultimate crop pattern it was assumed that the types of pasture designated as "meadow" and "marginal" would be located on present high water table lands and on hilly and rocky shallow lands, respectively. The type of pasture designated as "improved" would be situated on the better valley floor lands.

The truck crop class was taken to include potatoes, as well as any other similar crops adapted to the Basin. The hay and grain crop class includes wheat, barley, oats, and rye crops, which are either threshed or cut for hay depending upon quality and need. The field crop class includes silage crops, sugar beets, and corn, although such crops are not raised extensively in the Basin at present.

As has been indicated, the ultimate urban water requirement of the Klamath River Basin was forecast on a population basis, rather than from consideration of the land area devoted to urban purposes. For this reason, no attempt was made to delineate future increments to the urban area determined in the present land use survey. Lands required for urban use will generally be converted from other water service areas.

Lands classified as miscellaneous water service areas in the ultimate pattern of land use include parks, golf courses, cemeteries, farmsteads, and industrial sites situated outside of urban communities. Areas ultimately to be devoted to these types of land use were projected from the present pattern on the basis of expected expansion of related population, agriculture, and industry. As an example, the ultimate area of farmsteads was determined from its relationship with present and probable ultimate irrigated agricultural lands. Similarly, the expected ultimate industrial area was projected from the present on the basis of anticipated growth in the timber processing industry. This latter estimate was influenced by estimates of ultimate sustained yield of timber products, data for which were furnished by the United States Forest Service and private lumber and wood products companies.

Swamp and marsh lands throughout the Basin, other than those irrigable high water table lands which were determined to be in the "Vs" classification and suitable for irrigated pasture, were considered to be unsuitable for irrigation even under conditions of ultimate development. Such lands exist principally in the Klamath Marsh, along the Williamson River, in the Sycan Marsh, along the Wood River, and in Lower Klamath Lake. As these marshes are important to the Pacific migratory waterfowl flyway and would be difficult to reclaim, it was assumed that they would be used as migratory waterfowl preserves. Water evaporated and transpired from these lands was therefore considered to be beneficially used and was included in the estimated ultimate water requirment.

At the suggestion of the Bureau of Reclamation, it was assumed that approximately 11,000 acres in Lower Klamath Lake would be maintained through controlled water levels as marsh land for waterfowl refuge under ultimate conditions. This area, presently within the Lower Klamath Lake Wildlife Refuge, consists of water surface, marsh, and reclaimed land farmed to winter-irrigated grain. The remaining land within the boundaries of Lower Klamath Lake Wildlife Refuge was classified as irrigable.

The water surface areas of Upper Klamath Lake, the present confined Tule Lake, and other major controlled lakes or man-made reservoirs that will probably be constructed in the Basin to provide regulation of water supplies to meet ultimate requirements, including the features of the California Water Plan, were included in the pattern of land use. The areas considered are those of average water surface elevation. The area at average elevation was taken as two-thirds of the maximum area. The natural channels of streams and rivers, however, were not segregated in the ultimate pattern of land use.

Lands which failed to meet the minimum requirements for irrigated agriculture in one or more of the characteristics of soil, topography, or drainage, were considered to be unsuitable for future irrigation development. These lands, denoted as "lands not subject to intensive water service," are principally found in the rocky desert wastes and the rugged and generally forested mountain slopes. Although such lands may never be irrigated, it is reasonable to assume that to a limited extent they will be developed in the future to scattered residences, recreational areas, mines, and other appropriate establishments. It is believed that, in general, these types of development will receive water service in relatively small quantities through individually developed wells and surface diversions. Water requirements for these lands were based on per capita estimates.

Tables 27 and 28 present the forecast of the probable ultimate pattern of land use in the Klamath River Basin, Table 27 by hydrographic units and subunits, and Table 28 by counties.

UNIT USE OF WATER

The second major step in the evaluation of present and ultimate water requirements of the Klamath River Basin, following the determination of present water service areas and the probable ultimate land use pattern, was to establish appropriate unit values of water use for each of the classes and types of land use.

Unit values of consumptive use of water by irrigated crops were determined from the results of soil moisture depletion studies conducted on representative irrigated plots in the Klamath River Basin during the growing seasons of 1953 and 1954, correlated by an empirical relationship with climatological data.

TABLE 26

CLASSIFICATION OF POTENTIALLY IRRIGABLE LANDS WITHIN COUNTIES IN THE KLAMATH RIVER BASIN

(In acres)

State and* County	Irrigable land class															
	V	Vp	Vr	Vpr	Vw	Vs	H	Hp	Hr	Hpr	Ht	Htp	Htr	Htpr	*Un-segre-gated	Gross irri-gable area
Oregon																
Lake	1,290	0	0	0	15,120	0	120	0	0	0	0	0	0	0	5,600	22,130
Klamath	225,650	3,390	8,370	7,060	30,940	16,080	60,160	14,120	5,270	3,560	2,970	2,340	360	100	162,400	542,770
Jackson	20	0	0	0	0	0	130	30	0	0	100	0	0	0	0	280
Josephine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotals	226,960	3,390	8,370	7,060	46,060	16,080	60,410	14,150	5,270	3,560	3,070	2,340	360	100	168,000	565,180
California																
Modoc	49,580	0	100	460	7,230	320	5,140	350	490	0	0	0	0	0	0	63,670
Siskiyou	234,980	5,980	29,840	2,430	32,260	23,030	50,480	16,780	6,760	2,910	7,380	5,790	60	160	0	418,840
Trinity	3,060	0	1,120	0	0	0	7,490	100	240	0	790	0	0	0	0	12,800
Humboldt	1,630	0	160	0	0	0	3,440	0	0	0	300	0	0	0	0	5,530
Del Norte	2,370	0	0	0	370	0	20	0	0	0	0	0	0	0	0	2,760
Subtotals	291,620	5,980	31,220	2,890	39,860	23,350	66,570	17,230	7,490	2,910	8,470	5,790	60	160	0	503,600
APPROXIMATE TOTALS, KLAMATH RIVER BASIN	518,600	9,400	39,600	10,000	85,900	39,400	127,000	31,400	12,800	6,500	11,500	8,100	400	300	168,000	1,070,000

* Unsegregated land classified as irrigable by United States Bureau of Reclamation.

TABLE 27

PROBABLE ULTIMATE PATTERN OF LAND USE WITHIN HYDROGRAPHIC UNITS IN THE KLAMATH RIVER BASIN

(In acres)

Hydrographic unit and subunit		Type and class of land use													
		Irrigated lands									Miscel-laneous water service areas	Swamp and marsh lands	Principal reservoirs and lakes	Lands not subject to intensive water service	Total
			Pasture												
Refer-ence num-ber	Name	Alfalfa	Improved	Marginal	Meadow	Hay and grain	Orchard	Truck	Field crops	Net irri-gated area					
1	Williamson River	0	50,800	0	0	12,700	0	0	0	63,500	1,500	15,000	0	865,200	945,200
2	Sprague River	20,400	33,900	1,500	18,800	11,800	0	2,400	0	88,800	2,000	7,000	24,600	858,500	980,900
3	Upper Klamath Lake														
3A	Wood River	1,800	52,100	0	12,100	6,800	0	1,200	0	74,000	1,400	9,300	3,000	122,400	210,100
3B	Klamath Lake	2,300	7,300	100	11,500	4,400	0	1,400	0	27,000	300	0	65,000	155,800	248,100
	Subtotals	4,100	59,400	100	23,600	11,200	0	2,600	0	101,000	1,700	9,300	68,000	278,200	458,200
4	Lost River														
4A	Swan Lake	6,400	6,700	0	0	9,100	0	3,800	1,200	27,200	500	0	0	65,400	93,100
4B	Clear Lake	1,500	10,000	0	11,600	1,700	0	100	0	24,900	500	5,900	5,100	721,800	758,200
4C	Klamath Project	50,500	48,200	3,200	1,800	119,800	100	35,500	5,600	264,700	9,400	10,500	11,100	302,300	598,000
4D	Lava Beds	700	500	0	0	1,100	0	800	700	3,800	100	0	0	354,100	358,000
4E	Oklahoma	3,200	2,500	500	5,300	6,700	0	3,700	2,400	24,300	500	3,700	3,200	96,900	128,600
	Subtotals	62,300	67,900	3,700	18,700	138,400	100	43,900	9,900	344,900	11,000	20,100	19,400	1,590,500	1,935,900
5	Butte Valley														
5A	Macdoel	14,500	3,000	700	800	13,000	0	10,400	12,600	55,000	1,800	100	3,400	124,400	184,700
5B	Butte Creek	5,800	1,000	0	3,100	3,100	0	1,500	1,800	16,300	600	0	200	135,300	152,400
5C	Red Rock	3,100	1,600	700	0	2,500	0	500	1,000	9,400	200	0	[a]	57,100	66,700
	Subtotals	23,400	5,600	1,400	3,900	18,600	0	12,400	15,400	80,700	2,600	100	3,600	316,800	403,800
6	Shasta Valley														
6A	Yreka	2,200	1,300	400	0	900	0	100	200	5,100	1,100	0	[a]	33,700	39,900
6B	Little Shasta	16,700	8,900	600	2,000	6,200	0	1,000	1,900	37,300	1,400	0	2,600	84,400	125,700
6C	Gazelle-Grenada	12,200	6,500	200	3,700	4,500	0	700	1,500	29,300	700	0	1,300	66,800	98,100
6D	Big Springs-Juniper	6,100	4,300	200	1,000	1,800	0	200	600	14,200	300	0	100	100,300	114,900
6E	Grass Lake	800	600	0	0	0	0	0	0	1,400	0	1,300	0	15,300	18,000
6F	Parks Creek	1,700	3,100	100	1,800	300	0	0	100	7,100	100	0	0	25,800	33,000
6G	Upper Shasta	4,200	2,600	100	1,700	1,300	0	200	500	10,600	1,100	0	1,600	64,500	77,800
	Subtotals	43,900	27,300	1,600	10,200	15,000	0	2,200	4,800	105,000	4,700	1,300	5,600	390,800	507,400
7	Scott Valley														
7A	East Side	7,900	2,400	400	500	4,200	0	200	200	15,800	400	100	0	70,500	86,800
7B	Moffett Creek	2,100	800	200	0	700	0	100	200	4,100	200	0	400	74,400	79,100
7C	Quartz Valley	2,700	2,300	0	1,300	1,000	0	100	200	7,600	200	0	600	35,300	43,700
7D	West Side	3,300	6,300	400	4,900	5,900	0	0	0	20,800	400	100	300	91,300	112,900
7E	Callahan	1,500	1,100	1,200	100	700	0	0	0	4,600	100	0	1,200	95,100	101,000
	Subtotals	17,500	12,900	2,200	6,800	12,500	0	400	600	52,900	1,300	200	2,500	366,600	423,500

8	Salmon River														
8A	Wooley Creek	0	100	0	0	0	0	0	0	100	0	0	0	96,400	96,500
8B	North Fork of Salmon	0	0	0	0	0	0	0	0	0	100	0	3,800	152,800	156,700
8C	South Fork of Salmon	0	200	100	0	0	0	0	0	300	0	0	0	221,700	222,000
	Subtotals	0	300	100	0	0	0	0	0	400	100	0	3,800	470,900	475,200
9	Upper Trinity River	500	1,100	0	0	100	0	0	0	1,700	300	0	13,000	452,400	467,400
10	Lower Trinity River	1,500	2,300	400	0	700	400	200	0	5,500	200	0	34,700	818,300	858,700
11	Klamath River														
11A	Copco	1,400	1,300	100	400	700	0	100	200	4,200	100	0	800	231,600	236,700
11B	Hornbrook	1,000	1,200	700	0	500	0	0	100	3,500	500	0	600	239,900	244,500
11C	Ager	2,100	3,600	1,600	0	1,200	0	100	200	8,800	200	0	0	87,500	96,500
11D	Happy Camp	1,400	2,100	1,000	0	700	200	0	0	5,400	400	0	40,600	1,038,900	1,085,300
11E	Mouth of Klamath	300	1,600	0	300	0	0	500	0	2,700	600	0	8,300	308,600	320,200
	Subtotals	6,200	9,800	3,400	700	3,100	200	700	500	24,600	1,800	0	50,300	1,906,500	1,983,200
12	South Fork of Trinity River														
12A	Hyampom	300	500	100	0	100	100	0	0	1,100	0	0	6,000	395,300	402,600
12B	Hayfork	1,500	2,200	200	0	700	0	100	200	4,900	700	0	400	161,700	167,800
	Subtotals	1,800	2,700	300	0	800	100	100	200	6,000	700	0	6,400	557,300	570,400
	APPROXIMATE TOTALS, KLAMATH RIVER BASIN	181,600	274,000	14,700	82,700	224,900	800	64,900	31,400	875,000	28,000	53,000	232,000	8,822,000	10,010,000

TABLE 28

PROBABLE ULTIMATE PATTERN OF LAND USE WITHIN COUNTIES IN THE KLAMATH RIVER BASIN

(In acres)

State and county	Type and class of land use													
	Irrigated lands									Miscellaneous water service areas	Swamp and marsh lands	Principal reservoirs and lakes	Lands not subject to intensive water service	Total
	Alfalfa	Pasture		Meadow	Hay and grain	Orchard	Truck	Field crop	Net irrigated area					
		Improved	Marginal											
Oregon														
Lake	0	5,700	0	13,200	0	0	0	0	18,900	400	7,400	0	306,000	332,700
Klamath	72,400	195,600	4,800	36,300	112,500	100	26,400	3,400	451,500	12,900	28,500	96,400	2,523,800	3,113,100
Jackson	0	100	100	0	0	0	0	0	200	0	0	0	159,900	160,100
Josephine	0	0	0	0	0	0	0	0	0	0	0	0	3,600	3,600
Subtotals	72,400	201,400	4,900	49,500	112,500	100	26,400	3,400	470,600	13,300	35,900	96,400	2,993,300	3,609,500
California														
Modoc	5,800	7,400	0	6,300	24,300	0	10,600	1,100	55,500	1,100	4,800	1,300	689,900	752,600
Siskiyou	99,200	57,100	9,100	26,600	86,400	100	27,100	26,600	332,200	11,600	12,300	60,600	2,853,700	3,270,400
Trinity	2,800	4,600	500	0	1,200	200	200	300	9,800	1,100	0	40,900	1,583,800	1,635,600
Humboldt	1,200	2,100	200	0	500	400	100	0	4,500	200	0	32,700	562,800	600,200
Del Norte	200	1,400	0	300	0	0	500	0	2,400	600	0	0	138,500	141,500
Subtotals	109,200	72,600	9,800	33,200	112,400	700	38,500	28,000	404,400	14,600	17,100	135,500	5,828,700	6,400,300
APPROXIMATE TOTALS, KLAMATH RIVER BASIN	181,600	274,000	14,700	82,700	224,900	800	64,900	31,400	875,000	28,000	53,000	232,000	8,822,000	10,010,000

Soil moisture depletion studies were conducted on non-irrigated crops, fallow land, and native vegetation, for the purpose of evaluating effective precipitation. Detailed results of the plot studies, and a sample procedure for determining growing period consumptive use of water by the soil moisture depletion method, are presented in Appendix B.

Unit values of consumptive use of water for purposes other than irrigation were derived from available records of such use in the Klamath River Basin, and from the results of studies in other similar areas. Records of total water delivery to urban areas were reduced to per capita consumption values. Data relating to municipal water consumption in or adjacent to the Klamath River Basin are presented in Appendix C.

Unit values of consumptive use of water by swamp and marsh lands were derived from available pan evaporation records. Unit values of consumptive use of water by timber processing industries were obtained from records of actual use by private lumber and wood products companies and from data developed by the United States Forest Service. Unit values of consumptive use of water by recreational facilities in the forested areas, and by other miscellaneous developments were in most instances estimated in terms of per capita use, based upon applicable information from all available sources.

The basic procedure for estimating unit values of consumptive use of water by irrigated crops in the Klamath River Basin made use of the method evolved by Harry F. Blaney and Wayne D. Criddle, of the Soil Conservation Service of the United States Department of Agriculture, and presented in their report entitled "Determining Water Requirements in Irrigated Areas From Climatological and Irrigation Data," dated August, 1950. A description of the method as stated in that report follows:

> "Briefly, the procedure is to correlate existing consumptive use data with monthly temperature, monthly percentages of yearly daytime hours, precipitation, and growing or irrigation season use. Coefficients have been developed from existing measured consumptive use and temperature data and monthly per cents of yearly daytime hours. Thus, if only monthly temperature records are available and latitude is known, the consumptive use can be computed from the formula $U = KF$: where U equals consumptive use of water in inches for any period, $K =$ empirical consumptive-use coefficient, and $F =$ sum of the monthly consumptive use factors for the period (sum of the products of mean monthly temperature and monthly per cent of annual daytime hours)."

A description of the steps taken during the current studies to estimate unit values of total seasonal consumptive use of water by irrigated crops, effective precipitation, and consumptive use of applied water follows:

(1) Results of the soil moisture depletion plot studies, in terms of growing period consumptive use of water, were employed in the cited formula for the purpose of computing the coefficient of consumptive use applicable to the crop and area under consideration. The coefficient (K) was derived as the quotient of the measured growing period consumptive use of water (U) divided by the consumptive use factor (F). The factor (F) was the sum of the products of the average monthly temperatures during the period of the plot study and the monthly percent of annual daytime hours at the location of the plot. The computed coefficients of consumption for each crop were averaged, and the results are presented in Table B-6 of Appendix B.

(2) In a given hydrographic unit, the unit value of consumptive use of water for each irrigated crop during its growing season was computed as the product of the mean consumptive use factor (F) for the hydrographic unit and the appropriate coefficient of consumption (K), derived as in (1) above. For those crops not covered by the plot studies, the results of appropriate corresponding studies in other areas were utilized.

(3) Unit values of consumptive use of water for perennial crops during the nongrowing season, and for bare ground or stubble, were derived from soil moisture depletion studies and available pan evaporation records.

(4) Unit values of consumptive use of water during the growing period and the nongrowing period were added to obtain the total seasonal unit values of consumptive use of water.

(5) The portion of the unit seasonal value of consumptive use of water supplied by precipitation, referred to as "effective precipitation," equalled the sum of nongrowing season consumptive use of water, consumptive use of direct precipitation occurring during the growing season, and consumptive use of moisture stored in the soil during the nongrowing season and utilized during the following growing period. These items of precipitation do not subsequently appear as runoff.

(6) Unit values of consumptive use of applied water for each irrigated crop were derived as the difference between total seasonal consumptive use of water and effective precipitation.

Estimated unit seasonal values of consumptive use of applied irrigation water, effective precipitation, and total seasonal consumptive use of water by irrigated crops, presented in Table 29, represent the units of average use during a period of mean water supply and climate. A table presenting all items of the computation for the foregoing is found in Appendix B.

To account for differences in irrigation practices relating to irrigated pasture, the consumptive use of applied water by meadow pasture was estimated to

be 25 per cent greater than that by improved pasture. For marginal pasture, the consumptive use of applied water was estimated to be 25 per cent less than that of improved pasture.

From an analysis of water delivery records for 23 towns in or adjacent to the Klamath River Basin, the average daily per capita water delivery was determined to be approximately 200 gallons. This figure, which was used for estimates of water used by both present and ultimate urban and non-farm rural populations in the Basin, was based on total water deliveries to urban areas. The total delivery included water service to business and commercial establishments, industries within urban boundaries, residential areas, and losses from delivery systems. As many of the urban water deliveries in the Basin are now small and will probably remain so in the future, and as it is anticipated that sewage outflow and losses will not generally be available for direct reuse, the estimated unit delivery of water to urban communities was assumed to be equivalent both to their unit consumptive use of water and to their unit water requirement.

The estimated unit value of consumptive use of water for sawmill operations was one gallon per board foot of lumber produced; and for plywood manufacture, one gallon per board foot of logs processed. The unit values of consumptive use of water for wood products such as hard board and insulation board were determined to be 1,000 gallons per ton of chips; and for pulp and paper products 6,000 gallons per ton of chips. However, for these products the estimates of unit water requirements were considerably greater than the assigned unit consumptive use values. For hard board and wet form continuous process insulation board the unit value of water requirement was estimated to average about 10,000 gallons per ton of chips; and for pulp and paper products, 60,000 gallons per ton of chips. These requirements did not include water that may be needed to provide adequate dilution for waste effluent discharged into streams. This matter is discussed subsequently in this chapter under the heading of "Water Requirements of a Nonconsumptive Nature."

Consumptive use of applied water on farmsteads was estimated to be approximately 1.0 foot of depth of water per season, based upon experience in similar areas elsewhere in California. Remaining lands, classified as miscellaneous water service areas, were assigned an estimated unit seasonal value of consumptive use of applied water of 0.5 foot of depth.

Unit values of net reservoir evaporation are computed as reservoir surface evaporation in excess of precipitation during those months when monthly evaporation is greater than precipitation. Net reservoir evaporation represents water lost due to reservoir construction, in addition to water consumed on land in the reservoir before construction. Seasonal unit values were based on records of evaporation pans and atmometers maintained in the Klamath Project area, and in Butte, Shasta, and Scott Valleys.

Unit values of consumptive use on swamp and marsh lands were based on seasonal water surface evaporation data.

CONSUMPTIVE USE OF WATER

Estimates were made of present and probable ultimate consumptive use of water in the Klamath River Basin. The estimates were based on land use patterns and unit use of water as previously described.

Present Consumptive Use

The quantities of applied water presently used on irrigated lands, swamp and marsh areas, and miscellaneous water service areas were estimated by multiplying the acreage of each type of land use by its mean unit value of consumptive use of applied water. Consumptive use of water by urban lands was estimated as the product of the urban population and the per capita value of water use. Since present domestic, recreational, and industrial water consumption, in addition to that included in the present urban estimate, is relatively small, it was disregarded in computing total present consumptive use of water.

Tables 30 and 31 present, by hydrographic units and counties, respectively, the estimates of mean seasonal consumptive use of applied water on present water service areas in the Klamath River Basin.

Probable Ultimate Consumptive Use

The procedures utilized in estimating probable ultimate mean seasonal consumptive use of applied water in the Klamath River Basin were similar to those employed to estimate present consumptive use. The quantities of water that will be consumptively used on irrigated lands and miscellaneous water service areas were estimated by multiplying the forecast ultimate acreage of each type of land use by its respective mean unit seasonal value of consumptive use of applied water. Consumptive use of water for urban purposes, and for other beneficial purposes on lands not considered subject to intensive water service under ultimate conditions of development, was estimated as the product of population and the per capita value of water use.

The estimate of ultimate consumptive use of water by the timber industry, included in miscellaneous water service uses, was derived by multiplying the unit value of consumptive use of water in each timber product by the amount of the anticipated ultimate production on a sustained timber yield basis. For purposes of computing the total depletions of water supplies, the net evaporation from reservoirs that will probably be constructed to regulate the flow of streams in the Klamath River Basin, and the evapotranspiration from swamp and marsh land that will be utilized for migratory waterfowl, were considered

TABLE 29

ESTIMATED MEAN SEASONAL UNIT VALUES OF CONSUMPTIVE USE OF WATER IN THE KLAMATH RIVER BASIN

(In feet of depth)

Hydrographic Unit		Irrigated crops											
		Alfalfa			Improved pasture			Clover			Hay and grain		
Reference number	Name	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total
1	Williamson River	1.1	1.2	2.3	1.3	1.1	2.4	---	---	---	0.4	1.1	1.5
2	Sprague River	1.2	1.1	2.3	1.4	1.0	2.4	---	---	---	0.4	1.0	1.4
3	Upper Klamath Lake	1.2	1.1	2.3	1.4	1.0	2.4	---	---	---	0.4	1.0	1.4
4	Lost River (in Oregon)	1.6	1.0	2.6	1.8	0.9	2.7	1.8	0.9	2.7	0.6	1.0	1.6
4	Lost River (in California)	1.6	0.9	2.5	1.7	0.9	2.6	1.7	0.9	2.6	0.7	0.8	1.5
5	Butte Valley	1.4	1.0	2.4	1.6	0.9	2.5	1.6	0.9	2.5	0.5	1.0	1.5
6	Shasta Valley	1.9	1.1	3.0	2.1	1.0	3.1	---	---	---	0.6	1.0	1.6
7	Scott Valley	1.6	1.3	2.9	1.9	1.2	3.1	---	---	---	0.5	1.1	1.6
8	Salmon River	1.8	1.6	3.4	2.1	1.5	3.6	---	---	---	0.7	1.1	1.8
9	Upper Trinity River	1.7	1.5	3.2	2.0	1.4	3.4	---	---	---	0.6	1.1	1.7
10	Lower Trinity River	1.7	1.6	3.3	1.9	1.6	3.5	---	---	---	0.6	1.2	1.8
11	Klamath River	1.6	1.6	3.2	1.8	1.6	3.4	---	---	---	0.6	1.2	1.8
12	South Fork of Trinity River	1.7	1.5	3.2	1.9	1.4	3.3	---	---	---	0.6	1.1	1.7

TABLE 29—Continued

ESTIMATED MEAN SEASONAL UNIT VALUES OF CONSUMPTIVE USE OF WATER IN THE KLAMATH RIVER BASIN

(In feet of depth)

Hydrographic unit		Irrigated crops								
		Orchard			Potatoes and truck			Field crops		
Reference number	Name	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total
1	Williamson River	---	---	---	---	---	---	---	---	---
2	Sprague River	---	---	---	1.2	0.8	2.0	---	---	---
3	Upper Klamath Lake	---	---	---	1.2	0.8	2.0	---	---	---
4	Lost River (in Oregon)	1.2	1.0	2.2	1.2	0.8	2.0	0.8	1.0	1.8
4	Lost River (in California)	---	---	---	1.1	0.8	1.9	0.9	0.9	1.8
5	Butte Valley	1.0	1.1	2.1	1.1	0.8	1.9	0.7	1.1	1.8
6	Shasta Valley	1.4	1.1	2.5	0.9	0.9	1.8	0.9	1.0	1.9
7	Scott Valley	1.1	1.4	2.5	0.8	1.0	1.8	0.7	1.2	1.9
8	Salmon River	---	---	---	---	---	---	---	---	---
9	Upper Trinity River	---	---	---	---	---	---	---	---	---
10	Lower Trinity River	1.2	1.7	2.9	1.3	1.0	2.3	---	---	---
11	Klamath River	1.1	1.7	2.8	1.2	1.0	2.2	0.8	1.2	2.0
12	South Fork of Trinity River	1.2	1.5	2.7	1.2	1.0	2.2	0.9	1.1	2.0

to be items of consumptive use. Consumptive use from swamp and marsh lands was computed by multiplying the mean unit seasonal value of consumptive use in excess of mean seasonal precipitation by the acreage included in the ultimate pattern of land use.

Presented in Tables 32 and 33, by hydrographic units and counties, respectively, are the estimates of probable ultimate mean seasonal consumptive use of applied water in the Klamath River Basin.

WATER REQUIREMENTS

Requirements for irrigation water supplies in the Klamath River Basin were estimated by applying appropriate water service area efficiency factors to the computed consumptive use of applied water for each area under consideration. The resulting estimates represent the gross quantity of water which must be furnished at one or more strategically located points in the area. These quantities are believed to be sufficient to provide adequate irrigation water supplies to all irrigable lands and also for unavoidable losses of water incidental to such use.

Water requirements for urban lands, and for miscellaneous water service areas comprising farmsteads, golf courses, parks, cemeteries and similar developments, were assumed to be equal to their respective consumptive use, or delivery, of applied water. Urban water requirements were taken to include water sup-

TABLE 30

ESTIMATED MEAN SEASONAL CONSUMPTIVE USE OF APPLIED WATER ON PRESENT WATER SERVICE AREAS WITHIN HYDROGRAPHIC UNITS IN THE KLAMATH RIVER BASIN

(In acre-feet)

Hydrographic unit and subunit		Irrigated lands			Urban lands	Miscellaneous water service areas	Swamp and marsh lands	Principal reservoirs and lakes	Totals
Reference number	Name	Surface irrigated	Sub-irrigated	Total					
1	Williamson River	9,200	86,300	95,500	300	300	54,000	0	150,100
2	Sprague River	14,300	39,400	53,700	300	300	25,000	0	79,300
3	Upper Klamath Lake								
3A	Wood River	39,500	13,700	53,200	100	900	75,000	13,000	142,200
3B	Klamath Lake	13,000	3,800	16,800	0	200	34,000	150,000	201,000
	Subtotals	52,500	17,500	70,000	100	1,100	109,000	163,000	343,200
4	Lost River								
4A	Swan Lake	6,300	0	6,300	0	100	0	0	6,400
4B	Clear Lake	4,000	23,800	27,800	0	300	4,300	70,000	102,400
4C	Klamath Project	214,400	1,400	215,800	7,900	4,300	17,000	29,900	274,900
4D	Lava Beds	0	0	0	0	0	0	0	0
4E	Oklahoma	4,600	6,700	11,300	0	200	4,800	7,800	24,100
	Subtotals	229,300	31,900	261,200	7,900	4,900	26,100	107,700	407,800
5	Butte Valley								
5A	Macdoel	9,800	1,400	11,200	300	200	400	7,200	19,300
5B	Butte Creek	1,300	5,000	6,300	100	100	0	600	7,100
5C	Red Rock	0	0	0	0	0	0	100	100
	Subtotals	11,100	6,400	17,500	400	300	400	7,900	26,500
6	Shasta Valley								
6A	Yreka	400	100	500	1,200	100	0	100	1,900
6B	Little Shasta	20,000	5,600	25,600	200	400	0	300	26,500
6C	Gazelle-Grenada	11,600	8,700	20,300	100	200	0	600	21,200
6D	Big Springs-Juniper	6,300	2,900	9,200	0	100	0	300	9,600
6E	Grass Lake	0	800	800	0	0	3,700	0	4,500
6F	Parks Creek	2,900	4,700	7,600	0	100	0	0	7,700
6G	Upper Shasta	3,500	4,600	8,100	900	100	0	4,600	13,700
	Subtotals	44,700	27,400	72,100	2,400	1,000	3,700	5,900	85,100
7	Scott Valley								
7A	East Side	6,300	4,500	10,800	100	200	200	0	11,300
7B	Moffett Creek	900	1,100	2,000	0	100	0	0	2,100
7C	Quartz Valley	3,200	3,600	6,800	0	100	0	0	6,900
7D	West Side	8,600	18,500	27,100	100	300	200	0	27,700
7E	Callahan	2,600	1,300	3,900	100	100	0	0	4,100
	Subtotals	21,600	29,000	50,600	300	800	400	0	52,100
8	Salmon River								
8A	Wooley Creek	0	0	0	0	0	0	0	0
8B	North Fork of Salmon	0	0	0	100	0	0	0	100
8C	South Fork of Salmon	200	0	200	0	0	0	0	200
	Subtotals	200	0	200	100	0	0	0	300
9	Upper Trinity River	3,800	0	3,800	200	100	0	34,000	38,100
10	Lower Trinity River	900	0	900	1,100	0	0	0	2,000
11	Klamath River								
11A	Copco	1,000	300	1,300	0	100	100	2,400	3,900
11B	Hornbrook	3,300	100	3,400	200	0	0	0	3,600
11C	Ager	2,500	100	2,600	0	100	0	100	2,800
11D	Happy Camp	2,400	800	3,200	700	0	0	0	3,900
11E	Mouth of Klamath	400	400	800	200	0	0	0	1,000
	Subtotals	9,600	1,700	11,300	1,100	200	100	2,500	15,200
12	South Fork of Trinity River								
12A	Hyampom	600	0	600	100	0	0	0	700
12B	Hayfork	1,000	0	1,000	200	0	0	0	1,200
	Subtotals	1,600	0	1,600	300	0	0	0	1,900
	APPROXIMATE TOTALS, KLAMATH RIVER BASIN	398,800	239,600	638,000	14,500	9,000	219,000	321,000	1,202,000

TABLE 31

ESTIMATED MEAN SEASONAL CONSUMPTIVE USE OF APPLIED WATER ON PRESENT WATER SERVICE AREAS WITHIN COUNTIES IN THE KLAMATH RIVER BASIN

(In acre-feet)

State and county	Irrigated lands			Urban lands	Miscellaneous water service areas	Swamp and marsh lands	Principal reservoirs and lakes	Totals
	Surface irrigated	Sub-irrigated	Total					
Oregon								
Lake	2,100	32,000	34,100	0	100	26,000	0	60,200
Klamath	231,100	122,400	353,500	8,200	4,600	179,000	175,200	720,500
Jackson	200	0	200	0	0	0	0	200
Josephine	0	0	0	0	0	0	0	0
Subtotals	233,400	154,400	387,800	8,200	4,700	205,000	175,200	780,900
California								
Modoc	36,000	14,200	50,200	300	900	300	57,800	109,500
Siskiyou	122,600	70,600	193,200	4,200	3,300	13,800	54,400	268,500
Trinity	6,100	0	6,100	1,100	100	0	34,000	41,300
Humboldt	300	0	300	500	0	0	0	800
Del Norte	400	400	800	200	0	0	0	1,000
Subtotals	165,400	85,200	250,600	6,300	4,300	14,100	145,800	421,100
APPROXIMATE TOTALS, KLAMATH RIVER BASIN	398,800	239,600	638,000	14,500	9,000	219,000	321,000	1,202,000

plies needed for industrial purposes within urban areas. Water needed for industrial purposes outside the limits of urban areas, under ultimate conditions, was included in the requirement for miscellaneous water service areas. The industrial requirement was derived from estimates of sustained yield timber production and unit values of water use for timber and wood products manufacturing, and included both consumed and unconsumed processing water.

The net evaporation loss from reservoirs, considered as a water use in the hydrologic balance of a basin, was included as an item of water requirements. Evapotranspiration from swamp and marsh areas, only incidentally employed for beneficial purposes at the present time, was not considered to constitute a present water requirement. It is anticipated that these areas will be ultimately developed as migratory waterfowl reservations, with a resultant beneficial use of the water at that time. The ultimate water requirement for this purpose was assumed to equal the estimated seasonal consumptive use of applied water for promoting vegetative growth and providing for evaporation from water and wetted surfaces.

Determinations of present and probable ultimate water requirements were made for each hydrographic unit and subunit in the Basin. However, it should be noted that hydrographic unit requirements are not necessarily the sum of water requirements of subunits within the major unit. Return flows of unconsumed applied water, either on the surface or underground, from an upper subunit to a lower, may fulfill a portion of the requirement of the lower subunit without increasing the gross requirement of the hydrographic unit. Similarly, return flow from an upper hydrographic unit to a lower unit may fulfill a portion of the lower unit's requirement without adding to the over-all basin water requirement.

Water requirements in the Klamath River Basin were evaluated as they would occur during a season in which water supply and climate closely approached the mean, and under the assumption that a full supply of water would be available for all beneficial consumptive uses. It was recognized, however, that seasonal variations in climate will cause appreciable changes in seasonal water requirements. The most critical effect will occur during a hot, dry season with the resulting increased demand for water. Often the climatic conditions that cause increased water demand occur in years when precipitation and runoff are below normal. Seasonal variations in water requirements must be taken into consideration in planning future development of water resources.

Irrigation Water Service Area Efficiencies

Irrigation water service area efficiencies were evaluated from available data, and were used to compute water requirements for irrigated lands. The irrigation water service area efficiency refers to the ratio of the over-all consumptive use of applied irrigation water to the gross amount of water supplied to the service area to provide for the beneficial use and for incidental operating losses. Many irrigators are familiar with farm irrigation efficiency, the ratio of water consumptively used on the farm to the amount of water delivered to the farm. The scope of irrigation water service area efficiency is much broader since it de-

TABLE 32

PROBABLE ULTIMATE MEAN SEASONAL CONSUMPTIVE USE OF APPLIED WATER WITHIN HYDROGRAPHIC UNITS IN THE KLAMATH RIVER BASIN

(In acre-feet)

Hydrogrpahic unit and subunit: Reference number	Name	Irrigated lands	Urban lands	Miscellaneous water service areas	Swamp and marshlands	Principal reservoirs	Totals
1	Williamson River	71,000	700	1,400	21,000	0	94,100
2	Sprague River	114,900	800	1,900	15,400	73,700	206,700
3	Upper Klamath Lake						
3A	Wood River	99,900	600	1,300	20,500	13,000	135,300
3B	Klamath Lake	47,600	200	500	0	150,000	198,300
	Subtotals	147,500	800	1,800	20,500	163,000	333,600
4	Lost River						
4A	Swan Lake	33,200	300	500	0	0	34,000
4B	Clear Lake	46,700	200	500	15,900	16,400	79,700
4C	Klamath Project	298,300	9,000	5,800	28,500	29,900	371,500
4D	Lava Beds	4,200	200	200	0	0	4,600
4E	Oklahoma	32,100	200	500	9,900	7,800	50,500
	Subtotals	414,500	9,900	7,500	54,300	54,100	540,300
5	Butte Valley						
5A	Macdoel	54,400	900	1,200	200	8,500	65,200
5B	Butte Creek	20,400	300	500	0	600	21,800
5C	Red Rock	10,200	100	200	0	100	10,600
	Subtotals	85,000	1,300	1,900	200	9,200	97,600
6	Shasta Valley						
6A	Yreka	8,400	2,700	600	0	100	11,800
6B	Little Shasta	62,900	700	800	0	6,200	70,600
6C	Gazelle-Grenada	51,600	500	600	0	3,000	55,700
6D	Big Springs-Juniper	25,300	200	300	0	300	26,100
6E	Grass Lake	2,800	0	100	3,700	0	6,600
6F	Parks Creek	14,800	100	100	0	0	15,000
6G	Upper Shasta	19,600	3,800	900	0	4,600	28,900
	Subtotals	185,400	8,000	3,400	3,700	14,200	214,700
7	Scott Valley						
7A	East Side	21,400	900	400	100	0	22,800
7B	Moffett Creek	5,500	100	100	0	1,000	6,700
7C	Quartz Valley	12,500	200	200	0	1,300	14,200
7D	West Side	32,500	400	400	100	700	34,100
7E	Callahan	6,800	200	100	0	2,900	10,000
	Subtotals	78,700	1,800	1,200	200	5,900	87,800
8	Salmon River						
8A	Wooley Creek	200	100	100	0	0	400
8B	North Fork of Salmon	0	300	100	0	8,700	9,100
8C	South Fork of Salmon	600	300	100	0	0	1,000
	Subtotals	800	700	300	0	8,700	10,500
9	Upper Trinity River	3,000	800	300	0	34,000	38,100
10	Lower Trinity River	8,600	2,700	200	0	98,900	110,400
11	Klamath River						
11A	Copco	6,900	0	100	100	2,400	9,500
11B	Hornbrook	6,000	100	100	0	1,000	7,200
11C	Ager	15,100	100	200	0	0	15,400
11D	Happy Camp	8,200	4,200	800	0	108,600	121,800
11E	Mouth of Klamath	4,600	5,300	100	0	22,400	32,400
	Subtotals	40,800	9,700	1,300	100	134,400	186,300
12	South Fork of Trinity River						
12A	Hyampom	1,600	600	100	0	17,400	19,700
12B	Hayfork	7,700	1,100	200	0	1,000	10,000
	Subtotals	9,300	1,700	300	0	18,400	29,700
	APPROXIMATE TOTALS, KLAMATH RIVER BASIN	1,160,000	39,000	21,000	115,000	615,000	1,950,000

TABLE 33

PROBABLE ULTIMATE MEAN SEASONAL CONSUMPTIVE USE OF APPLIED WATER WITHIN COUNTIES IN THE KLAMATH RIVER BASIN

(In acre-feet)

State and county	Irrigated lands	Urban lands	Miscellaneous water service areas	Swamp and marshlands	Principal reservoirs	Totals
Oregon						
Lake	33,000	100	400	15,400	0	48,900
Klamath	575,700	10,900	9,400	41,500	248,900	886,400
Jackson	300	0	0	0	0	300
Josephine	0	0	0	0	0	0
Subtotals	609,000	11,000	9,800	56,900	248,900	935,600
California						
Modoc	64,700	500	1,100	14,100	4,200	84,600
Siskiyou	459,200	16,700	9,600	44,400	157,700	687,600
Trinity	15,800	3,500	400	0	112,400	132,100
Humboldt	6,700	1,900	500	0	91,300	100,400
Del Norte	4,100	5,300	100	0	0	9,500
Subtotals	550,500	27,900	11,700	58,500	365,600	1,014,200
APPROXIMATE TOTALS, KLAMATH RIVER BASIN	1,160,000	39,000	21,000	115,000	615,000	1,950,000

pends upon the effect of the irrigation efficiencies of all farms within the service area, as well as losses from district or private distribution systems and the opportunity for ultilization of return flows.

Basic data regarding present water service area efficiencies were analyzed from records of water delivery by irrigation districts in Shasta and Butte Valleys, and by the United States Bureau of Reclamation in the Klamath Project. By dividing estimates of consumptive use of applied water within the service areas by the measured amounts of water delivered to the service areas, efficiency factors were determined to vary from about 30 to 60 per cent. The values derived for specific areas were used to estimate both present and ultimate water service area efficiencies for all the hydrographic units. In addition to the computed values, consideration was given to other factors such as soil types, topography, types of irrigated crops, irrigation practices, available water supply, diversion works, and the opportunity for use of return water within the service area. A considerable element of experience and judgment was involved in the evaluation of the factors.

Estimates of present and probable ultimate irrigation water service area efficiencies are presented in Table 34. Present irrigation water service area efficiencies, derived as described above, were applied to surface irrigated lands. However, there are large areas of high water table meadow pasture lands within the Klamath River Basin that are naturally subirrigated. Since these lands receive water by natural means, it was assumed that there are no irrigation losses involved. The irrigation efficiency of meadow pasture land was therefore assumed to approach 100 per cent. The present average irrigation water service area efficiencies, shown in Table 34, are higher than those for surface irrigated lands because of the effect of the subirrigated lands.

Irrigation practices will undoubtedly improve in the future, and it was assumed that irrigation water service area efficiencies will be higher. As projects are developed to conserve and deliver water for agriculture, better conveyance systems will reduce transmission losses. Also, in view of estimated future costs of water, farmers will strive for more efficient use of water to reduce operating costs. It was assumed that all high water table lands now supporting meadow pasture would be converted to surface irrigated agricultural lands to gain better yields. The ultimate average water service area efficiency for most subunits was assumed to be 50 per cent. However, for Swan Lake, Butte Valley, and Scott Valley, where much of the supply would be pumped from ground water and return flows would percolate back into the ground water basin, higher efficiencies ranging from 60 to 75 per cent were used. Higher irrigation service area efficiencies were used in the Klamath Project and Little Shasta hydrographic subunits because it was assumed that significant utilization would be made of return flows.

Present Water Requirements

Determination of the present mean seasonal water requirement of the Klamath River Basin for irrigated crops was based upon consumptive use of applied water by the crop pattern existing in 1952-53, but under mean conditions of water supply and climate, with irrigation water service area efficiency values explained in the preceding section. As previously stated, the present water requirement for urban communities was assumed to equal the present delivery for such purpose. Similarly, the estimated water re-

quirement of miscellaneous water service areas was assumed to be the same as the consumptive use of applied water.

In comparing the estimated present water requirement to the available unregulated water supply in Shasta Valley, where stream flow records during the irrigation season are available for 19 years, it was found that the present requirement approximates the average volume of runoff during the irrigation season. Since the present irrigatiou development in this valley is dependent upon unregulated stream flow for most of its water supply, certain lands with water rights of low priority suffer shortages of water when runoff during the irrigation season is less than average.

In Scott Valley, studies of surface and underground water supplies indicate that the present water requirements for irrigation are within the range of the average available water supply and the capacity of present irrigation works. In this valley, there is evidence that additional conservation works, or development of underground supplies, would be necessary to meet present water requirements during seasons of extremely low runoff.

Present water requirements in Butte Valley are met by diversions from Butte Creek, and by ground water pumping. Because unregulated surface runoff percolates to the underlying ground water basin, future surface water storage developments do not appear to be warranted. Studies indicate that ground water yields, combined with the existing surface diversions, are adequate to meet present requirements, but that ground water supplies for additional development are limited.

The estimated present seasonal water requirement of the Klamath Project Subunit approximates the amount of water diverted seasonally for the Klamath Project. It is indicated that the present requirement can be met by yield from existing works of the project, even during seasons of extremely low runoff.

Estimates of present mean seasonal water requirements for each hydrographic unit and subunit of the Klamath River Basin are presented in Table 35. Table 36 summarizes these data for the portion of each county within the Basin.

TABLE 34

ESTIMATED PRESENT AND PROBABLE ULTIMATE IRRIGATION WATER SERVICE AREA EFFICIENCIES WITHIN HYDROGRAPHIC UNITS IN THE KLAMATH RIVER BASIN

(In per cent)

Hydrographic unit and subunit		Irrigation water service area efficiency		
		Present		Ultimate
Reference number	Name	Surface irrigated lands	Average for unit or subunit	Average for unit or subunit
1	Williamson River	30	80	50
2	Sprague River	30	55	50
3	Upper Klamath Lake			
3A	Wood River	40	50	50
3B	Klamath Lake	40	45	50
4	Lost River			
4A	Swan Lake	50	75	75
4B	Clear Lake	30	50	50
4C	Klamath Project	55	55	65
4D	Lava Beds	*	*	50
4E	Oklahoma	40	60	50
5	Butte Valley			
5A	Macdoel	40	45	60
5B	Butte Creek	30	65	50
5C	Red Rock	*	*	50
6	Shasta Valley			
6A	Yreka	40	50	50
6B	Little Shasta	65	80	65
6C	Gazelle-Grenada	50	75	50
6D	Big Springs-Juniper	45	65	50
6E	Grass Lake	*	100	50
6F	Parks Creek	40	75	50
6G	Upper Shasta	40	75	50
7	Scott Valley			
7A	East Side	40	55	50
7B	Moffett Creek	40	60	50
7C	Quartz Valley	40	60	50
7D	West Side	40	65	60
7E	Callahan	30	40	40
8	Salmon River			
8A	Wooley Creek	*	*	50
8B	North Fork of Salmon	*	*	50
8C	South Fork of Salmon	30	30	50
9	Upper Trinity River	30	30	50
10	Lower Trinity River	30	30	50
11	Klamath River			
11A	Copco	30	35	50
11B	Hornbrook	30	30	50
11C	Ager	30	30	50
11D	Happy Camp	30	35	50
11E	Mouth of Klamath	30	50	50
12	South Fork of Trinity River			
12A	Hyampom	30	30	50
12B	Hayfork	30	30	50

* No irrigation development at present.

Probable Ultimate Water Requirements

In general, the ultimate water requirements of the Klamath River Basin were estimated by procedures similar to those utilized in the case of the present requirement. For irrigated lands, which will undoubtedly continue to constitute the largest single water requirement in the Basin, values of consumptive use of applied water, as determined for the ultimate crop pattern under mean conditions of water supply and climate, were divided by appropriate irrigation water service area efficiency factors to estimate ultimate irrigation water requirements.

The urban water requirement was assumed to equal the ultimate water delivery to urban areas as forecast on a population-per capita water use basis. The ultimate requirement of farmsteads was assumed to equal the estimated consumptive use of applied water. The amount of the ultimate water requirement for industrial purposes was estimated on a unit produc-

TABLE 35

ESTIMATED PRESENT MEAN SEASONAL WATER REQUIREMENTS WITHIN HYDROGRAPHIC UNITS IN THE KLAMATH RIVER BASIN

(In acre-feet)

Hydrographic unit and subunit		Water requirements					
Reference number	Name	Irrigated lands	Urban lands	Miscellaneous water service areas	Swamp and marshland	Principal reservoirs and lakes	Approximate total requirement
1	Williamson River	117,000	300	300	54,000	0	172,000
2	Sprague River	87,800	300	300	25,000	0	113,000
3	Upper Klamath Lake						
3A	Wood River	112,500	100	900	75,000	13,000	202,000
3B	Klamath Lake	36,300	0	200	34,000	150,000	220,000
	Subtotals	148,800	100	1,100	109,000	163,000	422,000
4	Lost River						
4A	Swan Lake	8,400	0	100	0	0	8,000
4B	Clear Lake	46,000	0	300	4,300	70,000	121,000
4C	Klamath Project	384,000	7,700	4,100	17,000	29,900	443,000
4D	Lava Beds	0	200	0	0	0	0
4E	Oklahoma	18,200	0	200	4,800	7,800	31,000
	Subtotals	456,600	7,900	4,700	26,100	107,700	603,000
5	Butte Valley						
5A	Macdoel	26,000	300	200	400	7,200	34,000
5B	Butte Creek	9,300	100	100	0	600	10,000
5C	Red Rock	0	0	0	0	100	0
	Subtotals	35,300	400	300	400	7,900	44,000
6	Shasta Valley						
6A	Yreka	1,000	1,200	100	0	100	2,000
6B	Little Shasta	31,000	200	400	0	300	32,000
6C	Gazelle-Grenada	26,100	100	200	0	600	27,000
6D	Big Springs-Juniper	14,000	0	100	0	300	15,000
6E	Grass Lake	800	0	0	3,700	0	5,000
6F	Parks Creek	9,800	0	100	0	0	10,000
6G	Upper Shasta	10,800	900	100	0	4,600	16,000
	Subtotals	93,500	2,400	1,000	3,700	5,900	107,000
7	Scott Valley						
7A	East Side	20,200	100	200	200	0	21,000
7B	Moffett Creek	3,400	0	100	0	0	4,000
7C	Quartz Valley	11,600	0	100	0	0	12,000
7D	West Side	40,000	100	300	200	0	40,000
7E	Callahan	10,000	100	100	0	0	10,000
	Subtotals	85,200	300	800	400	0	87,000
8	Salmon River						
8A	Wooley Creek	0	0	0	0	0	0
8B	North Fork of Salmon	0	100	0	0	0	0
8C	South Fork of Salmon	700	0	0	0	0	1,000
	Subtotals	700	100	0	0	0	1,000
9	Upper Trinity River	12,600	200	100	0	34,000	47,000
10	Lower Trinity River	3,200	1,100	0	0	0	4,000
11	Klamath River						
11A	Copco	3,600	0	100	100	2,400	6,000
11B	Hornbrook	10,800	200	0	0	0	11,000
11C	Ager	8,600	0	100	0	100	9,000
11D	Happy Camp	8,700	700	0	0	0	9,000
11E	Mouth of Klamath	1,700	200	0	0	0	2,000
	Subtotals	33,400	1,100	200	100	2,500	37,000
12	South Fork of Trinity River						
12A	Hyampom	2,000	100	0	0	0	2,000
12B	Hayfork	3,300	200	0	0	0	4,000
	Subtotals	5,300	300	0	0	0	6,000
	APPROXIMATE TOTAL, KLAMATH RIVER BASIN	1,080,000	14,000	9,000	219,000	321,000	1,643,000

TABLE 36

ESTIMATED PRESENT MEAN SEASONAL WATER REQUIREMENTS WITHIN COUNTIES IN THE KLAMATH RIVER BASIN

(In acre-feet)

State and county	Water requirements					Approximate total requirement
	Irrigated lands	Urban lands	Miscellaneous water service areas	Swamp and marshland	Principal reservoirs and lakes	
Oregon						
Lake	32,200	0	100	26,000	0	58,000
Klamath	610,300	8,200	4,600	179,000	175,200	977,000
Jackson	700	0	0	0	0	1,000
Josephine	0	0	0	0	0	0
Subtotal	643,200	8,200	4,700	205,000	175,200	1,036,000
California						
Modoc	94,300	300	900	300	57,800	154,000
Siskiyou	319,200	4,200	3,300	14,000	54,000	395,000
Trinity	20,300	1,100	100	0	34,000	55,000
Humboldt	1,100	500	0	0	0	2,000
Del Norte	1,700	200	0	0	0	2,000
Subtotal	436,600	6,300	4,300	14,000	145,800	608,000
APPROXIMATE TOTALS, KLAMATH RIVER BASIN	1,080,000	14,000	9,000	219,000	321,000	1,643,000

tion basis. An allowance was made for an ultimate water requirement for swamp and marsh areas located in the Klamath and Sycan Marshes and the Wood River and Lower Klamath Lake areas, under the assumption that these areas will be ultimately developed as migratory waterfowl reservations, and that this employment of water will be beneficial.

The sum of the estimated ultimate mean seasonal water requirements of the component hydrographic subunits of the Klamath River Basin is about 2,900,000 acre-feet. The topography and land capabilities are such that approximately 2,300,000 acre-feet per season will be required in that portion of the Basin, tributary to the Klamath River, downstream to and including Scott Valley. The greatest use of return water in the Basin is that made possible by Upper Klamath Lake, where return flow from upstream hydrographic units can be diverted for reuse in the Lost River Hydrographic Unit. Opportunity for reuse of return flow also exists between subunits in the Lost River, Butte Valley, Shasta Valley, and Scott Valley Hydrographic Units.

In Table 37 estimates of probable ultimate mean seasonal water requirements are presented for hydrographic units and subunits within the Klamath River Basin. Corresponding estimates for the portion of each state and county within the Basin are presented in Table 38.

DEMANDS FOR WATER

The term, "Demands for Water," as used in this bulletin, refers to factors pertaining to specific rates, times, and places of delivery of water, quality of water, etc., imposed by the control, development, and use of water for beneficial purposes. Those demands relating to times, rates, and places of delivery of irrigation water, and permissible deficiencies in application of irrigation water, which must be given consideration in preliminary design of works to meet supplemental irrigation water requirements, are discussed in the following sections.

Application of Irrigation Water

Satisfaction of the consumptive water requirement of irrigated crops necessitates an application of water in excess of consumptive use. The amount of water applied and the resulting irrigation efficiency are dependent upon topography, soil type, soil depth, root zone of the crop, and drainage characteristics of the irrigated land, as well as the nature of irrigation systems and practices. While maximum obtainable irrigation efficiencies are limited by the physical characteristics of the land, those achieved through present practice in the Klamath River Basin are generally much lower than this maximum, and vary considerably with the type of irrigated agriculture.

The better irrigation practices in the Klamath River Basin generally occur in the more intensively developed areas of the Klamath Project and in Butte Valley. In these areas good irrigation systems and practices, such as border-check irrigation for grain, alfalfa, and pastures, and furrow irrigation for potatoes and field crops are used. The soils are permeable, permitting deep penetration without waste of excessive amounts of water at the ends of the fields. The average seasonal depth of applied water on fields in the Klamath Project during recent years was de-

TABLE 37

ESTIMATED PROBABLE ULTIMATE MEAN SEASONAL WATER REQUIREMENTS WITHIN HYDROGRAPHIC UNITS IN THE KLAMATH RIVER BASIN

(In acre-feet)

Hydrographic unit and subunit		Mean seasonal water requirements						
Reference number	Name	Irrigated lands	Urban lands	Miscellaneous water service areas	Swamp and marsh-lands	Net reservoir evaporation	Lands not subject to intensive water service	Approximate totals
1	Williamson River	142,100	700	1,400	21,000	0	300	166,000
2	Sprague River	229,800	800	1,900	15,400	73,700	300	322,000
3	Upper Klamath Lake							
3A	Wood River	199,900	600	1,300	20,500	13,000	a	235,000
3B	Klamath Lake	95,200	200	500	0	150,000	a	246,000
	Subtotals	295,100	800	1,800	20,500	163,000		481,000
4	Lost River							
4A	Swan Lake	44,300	300	500	0	0	0	45,000
4B	Clear Lake	93,300	200	500	15,900	16,400	200	127,000
4C	Klamath Project	459,000	9,000	5,800	28,500	29,900	100	532,000
4D	Lava Beds	8,300	200	200	0	0	100	9,000
4E	Oklahoma	64,200	200	500	9,900	7,800	a	82,000
	Subtotals	669,100	9,900	7,500	54,300	54,100	400	795,000
5	Butte Valley							
5A	Macdoel	90,600	900	1,200	200	8,500	a	101,000
5B	Butte Creek	40,800	300	500	0	600	a	42,000
5C	Red Rock	20,500	100	200	0	100	a	21,000
	Subtotals	151,900	1,300	1,900	200	9,200		164,000
6	Shasta Valley							
6A	Yreka	16,700	2,700	4,600	0	100	a	24,000
6B	Little Shasta	96,800	700	800	0	6,200	a	105,000
6C	Gazelle-Grenada	103,000	500	600	0	3,000	a	107,000
6D	Big Springs-Juniper	50,800	200	300	0	300	a	52,000
6E	Grass Lake	5,600	0	100	3,700	0	100	9,000
6F	Parks Creek	29,700	100	100	0	0	100	30,000
6G	Upper Shasta	39,200	3,800	6,700	0	4,600	a	54,000
	Subtotals	341,800	8,000	13,200	3,700	14,200	200	381,000
7	Scott Valley							
7A	East Side	42,700	900	400	100	0	a	44,000
7B	Moffett Creek	11,100	100	100	0	1,000	a	13,000
7C	Quartz Valley	25,100	200	200	0	1,300	a	27,000
7D	West Side	54,200	400	400	100	700	200	56,000
7E	Callahan	16,900	200	100	0	2,900	100	20,000
	Subtotals	150,000	1,800	1,200	200	5,900	300	160,000
8	Salmon River							
8A	Wooley Creek	400	100	100	0	0	a	1,000
8B	North Fork of Salmon	0	300	100	0	8,700	100	9,000
8C	South Fork of Salmon	1,200	300	100	0	0	100	2,000
	Subtotals	1,600	700	300	0	8,700	200	12,000
9	Upper Trinity River	6,000	800	300	0	34,000	100	41,000
10	Lower Trinity River	17,300	2,700	200	0	98,900	300	120,000
11	Klamath River							
11A	Copco	13,700	0	100	100	2,400	100	16,000
11B	Hornbrook	12,100	100	100	0	1,000	100	13,000
11C	Ager	30,200	100	200	0	0	a	31,000
11D	Happy Camp	16,400	4,200	800	0	108,600	300	130,000
11E	Mouth of Klamath	9,200	5,300	500	0	22,400	100	38,000
	Subtotals	81,600	9,700	1,700	100	134,400	600	228,000
12	South Fork of Trinity River							
12A	Hyampom	3,300	600	100	0	17,400	100	21,000
12B	Hayfork	15,400	1,100	200	0	1,000	100	18,000
	Subtotals	18,700	1,700	300	0	18,400	200	39,000
	APPROXIMATE TOTALS, KLAMATH RIVER BASIN	2,105,000	39,000	32,000	115,000	615,000	3,000	2,909,000

a Water requirement estimated to be less than 50 acre-feet.

TABLE 38

ESTIMATED PROBABLE ULTIMATE MEAN SEASONAL WATER REQUIREMENTS WITHIN COUNTIES IN THE KLAMATH RIVER BASIN

(In acre-feet)

State and county	Mean seasonal water requirements						Approximate totals
	Irrigated lands	Urban lands	Miscellaneous water service areas	Swamp and marsh-lands	Net reservoir evaporation	Lands not subject to intensive water service	
Oregon							
Lake	66,000	100	400	15,400	0	100	82,000
Klamath	1,031,000	10,900	9,300	41,500	248,900	700	1,342,000
Jackson	700	0	0	0	0	[a]	1,000
Josephine	0	0	0	0	0	300	0
Subtotals	1,097,700	11,000	9,700	56,900	248,900	1,100	1,425,000
California							
Modoc	111,000	500	1,300	14,100	4,200	200	131,000
Siskiyou	843,000	16,700	19,000	44,400	157,700	900	1,082,000
Trinity	30,200	3,500	800	0	112,400	500	148,000
Humboldt	15,000	1,900	500	0	91,300	200	109,000
Del Norte	8,000	5,300	400	0	0	[a]	14,000
Subtotals	1,007,200	27,900	22,000	57,800	365,600	1,800	1,484,000
APPROXIMATE TOTALS, KLAMATH RIVER BASIN	2,105,000	39,000	32,000	115,000	615,000	3,000	2,909,000

[a] Water requirement estimated to be less than 50 acre-feet

termined from project records to be about 2.3 feet. Average irrigation efficiency was estimated to be about 62 per cent. This value, however, reflects delivery of water to a large included acreage of grain land, which usually receives only one irrigation per season.

In Butte Valley the estimated average depth of applied water in the Butte Valley Irrigation District in 1953-1954 amounted to 3.7 feet, and the irrigation efficiency was estimated to be 36 per cent. Even though such efficiency appears to be somewhat low, the irrigation practices are good. There are large unavoidable percolation losses through the light sandy soils, and large quantities of water are applied to potatoes which are irrigated every five to seven days during July and August. Grain, hay, pasture, and alfalfa, also prominent among the irrigated crops in Butte Valley, require irrigation at about 2-week intervals.

Throughout the remainder of the Klamath River Basin, records of application of irrigation water are available only for Shasta Valley. The seasonal application varies from about two feet to eight feet in depth, depending partly on the availability of the water supply. The normal present average seasonal depth of application was indicated to be about 4.5 feet, for which the irrigation efficiency was estimated to be about 30 per cent.

Irrigated crops in Shasta Valley consist mainly of pasture and alfalfa. Although there is a trend toward improved irrigation facilities, little of the land is leveled, and most land is irrigated by wild-flooding methods. Because water supplies are frequently curtailed before the irrigation season is over, there is a tendency to begin irrigating early, and to apply large amounts of water during the spring. Conditions resulting from over-irrigation and lack of adequate drainage may be observed in the field. During 1921-22 and 1922-23, when distribution of water was administered by the Division of Water Resources for the purpose of determining water rights in three irrigation districts in Shasta Valley, an average seasonal depth of application of 3.6 feet was found to be ample for crop production.

Monthly Demands for Irrigation Water

The climate prevailing throughout the Klamath River Basin generally limits the normal irrigation season to the period from April 1st to the end of September. This is due to prevalent low fall and winter temperatures in the upper portion of the Basin, and to heavy rainfall near the coast. Seasonal variations in precipitation, however, may make irrigation necessary in some sections as early as March, or retard the beginning of the irrigation season until late in May. Should subnormal precipitation occur in September and October, irrigation is continued on pasture land wherever a water supply is available.

The monthly demands for water in terms of the seasonal total demand, were determined through study of records of monthly diversions for irrigation by organized water service agencies in Shasta Valley and on the Klamath Project.

In the Klamath Project, a demand for irrigation water occurs throughout the season because of the practice of pre-irrigating and winter flooding grain lands. During the period from 1938-39 through 1949-50, a total of about four per cent of the seasonal water requirement was supplied, on the average, during the months of October through March. Monthly irrigation demands in the Klamath Project, during the growing period from April through September, vary somewhat from those estimated for the remainder of the Basin because of the predominance of potato and grain crops.

Monthly demands for irrigation water, estimated from records of diversions in Shasta Valley from 1935-36 through 1952-53, were assumed to be representative of such demands throughout the remainder of the Klamath River Basin. The principal irrigated crops grown in Shasta Valley were pasture, alfalfa, and grain.

Estimated average monthly distribution of demands for irrigation water in the Klamath River Basin are given in Table 39.

Permissible Deficiencies in Application of Irrigation Water

There is little opportunity to determine deficiencies in application of irrigation water that might be endured without permanent injury to perennial crops in the Klamath River Basin, except through records maintained by Shasta River Watermaster. From the many records of operation of the Klamath Project, there is no indication of a past deficiency in water supply. Records of diversion to the Klamath Project show larger than normal diversions during seasons of subnormal water supply.

By using the estimated value for full natural runoff of the Shasta River near Yreka, in terms of per cent of the seasonal mean, it was found that the two most critical water supply seasons occurred in 1930-31 and 1933-34, in both of which the runoff was about 60 per cent of the mean. During the entire period from 1928-29 through 1936-37, however, the seasonal runoff of the Shasta River varied between a maximum of about 70 per cent of the mean and a minimum of 60 per cent. There is no evidence of extensive loss of irrigated perennial crops during these dry seasons, although irrigation practices were necessarily somewhat adapted to the available water supply. Such drought conditions, however, may cause a decrease in crop yields, especially of alfalfa.

Even when seasonal surface runoff drops to the critical stage, there is generally sufficient water to provide two irrigations during April or May to most irrigated lands in the Klamath River Basin. This is enough to meet the needs of pasture, grain, hay, and at least one cutting of alfalfa. After irrigation and one cutting, alfalfa will produce a stand suitable for pasturage and, with an additional irrigation or sufficient summer precipitation, a second cutting. If irrigation is withheld, alfalfa will usually become dormant for the remainder of the season without permanent injury to the plants. During a short water supply season, runoff usually fails rapidly in June. Allocation of the available water is then generally dependent upon priority of water rights, and the water is used primarily to sustain pastures.

During 1922-23, the distribution of water among members of the Shasta River Water Users Association and the Grenada Irrigation District was administered by the California Division of Water Resources. Although the natural runoff of the Shasta River during this season was only 68 per cent of the mean, there was sufficient water to meet the requirements of the two agencies. Gross diversions from the Shasta River were 3.5 and 4.2 feet of depth, respectively, for the Shasta River Water Users Association and the Grenada Irrigation District. It was also noted that during 1922-23 the attained irrigation efficiencies were higher than during 1951-52 and 1952-53, which were seasons with plentiful water supplies.

While precise information is not available, the foregoing records of operation in Shasta Valley concur generally with the results of a previous study made of endurable irrigation deficiencies by the Division of Water Resources in the Sacramento Valley. From this earlier study, it is indicated that a maximum deficiency of 35 per cent of the full seasonal irrigation water requirement can be endured without permanent damage to most perennial crops, if the deficiency occurs only at relatively long intervals. It was also indicated that smaller deficiencies occurring at relatively frequent intervals can be endured without serious economic hardship.

TABLE 39

ESTIMATED AVERAGE MONTHLY DISTRIBUTION OF DEMAND FOR IRRIGATION WATER IN THE KLAMATH RIVER BASIN

(In per cent of seasonal total)

Month	Klamath Project subunit	Remainder of Klamath River Basin
October	1.4	0
November	0.4	0
December	0.3	0
January	0.5	0
February	0.5	0
March	1.2	0.1
April	8.4	10.2
May	14.6	18.3
June	18.6	16.6
July	25.3	21.3
August	19.5	20.1
September	9.3	13.4
TOTALS	100.0	100.0

Migratory waterfowl rising from Lower Klamath Lake marshes

Eastman's Studio, Susanville, photograph

Inaccessible mountain lakes abound in Siskiyou and Trinity Counties

Eastman's Studio, Susanville, photograph

WATER REQUIREMENTS OF A NONCONSUMPTIVE NATURE

In evaluating water requirements of the Klamath River Basin, consideration should be given to such nonconsumptive water requirements as presently exist or as may develop in the Basin in the future. The term "nonconsumptive use of water," as used in the following discussion, refers to any beneficial use which does not cause impairment of the quantity or quality of the water supply. Nonconsumptive uses of water most prevalent in the Basin at the present time are those for recreation, fish and wildlife propagation and preservation, hydroelectric power production, mining, and for the timber industry.

An important factor in determining the quantity of water available for beneficial uses, which may be of greater future significance in this region as valley lands become more highly developed, is flood control. Flood control for rain floods, whether achieved by channelization or by storage, has as its objective the movement of flood flows to the ocean as rapidly as possible within channel flow capacities, and the provision of the maximum feasible protection against flooding of developed areas. Flood runoff when so disposed is largely unavailable for other purposes, and usually results in a net loss to the available water supply. However, storage dedicated to the control of snowmelt floods can generally be used for conservation purposes, after the danger of seasonal floods has lessened.

Requirements for Fish, Wildlife, and Recreation

The investigation of water requirements for fish, wildlife and recreation for the Klamath River Basin was made by the California Department of Fish and Game under a cooperative agreement. A complete report of this study covering fishing, hunting, trapping, and recreation, as well as an appraisal of local water development projects, is included as Appendix D. However, a brief discussion of this subject is covered in the following paragraphs.

The stream system of the Klamath River Basin presently supports one of the finest sport fisheries in the nation, as well as a significant commercial fishery at sea. The lower 200 miles of river channel is considered to be a prime source of such anadromous fishes as king salmon and steelhead rainbow trout. These oceangoing fishes are also found in quantity in the Salmon, Shasta, Scott, and Trinity Rivers, and their tributaries.

Commercial fishing for salmon on the lower reaches of the Klamath River reached a high state of development in the early 1900's. However, this was abolished by legislation in 1933. Since that time, the salmon and steelhead fisheries have been the Klamath's greatest attraction to sportsmen and tourists. This attraction is further enhanced by the abundance of other game fishes, including several varieties of resident trout, which are prevalent in most of the streams and lakes in the Basin.

In addition to the importance of streams in the Basin to sportsmen, the Klamath River and several of its tributaries below Copco Dam provide spawning grounds for salmon which are taken commercially and by sportsmen in the Pacific Ocean. Records of commercial salmon landings in California's ocean waters during 1955 indicate that approximately 109,000 salmon contributed by the Klamath River system were taken at sea, and that these fish had an estimated retail value of over $1,000,000. Data illustrating the economic value of the sport and commercial fishery in the California portion of the Basin are presented in Appendix D.

The greatest amount of angling is for three species of fishes: steelhead, king salmon, and silver salmon. During spring and early summer, fishing is carried on for the young steelhead and to some extent for young silver salmon. During the summer and autumn there is considerable angling in the Klamath estuary and lower reaches for adult steelhead, and for both species of adult salmon. The sport fishery for adult steelhead is most intensive in the lower Klamath River in the early fall, but is continuous throughout the Basin, particularly in the Trinity River, over the entire open season from May through February.

Adult king salmon enter the Klamath River from the ocean in two well-defined spawning runs. The spring run begins in late March, reaches a peak in May, and diminishes to the vanishing point by the end of June. The summer or fall run usually begins entering the Klamath estuary about the first of July. It increases gradually through that month, reaches a peak in August, declines steadily through September, and practically disappears by the beginning of winter. Both species of salmon spawn in the fall and early winter, with the kings reaching a spawning peak usually in October and November and the silvers a short time after.

While king salmon spawn principally in larger streams, silver salmon and steelhead usually seek out smaller tributaries. Steelhead are present in the waters of the Klamath and Trinity Rivers the year around, although the main adult steelhead migrations from the sea take place in June and July and again in the fall. Steelhead spawn from late February through the early part of June, with spawning activity reaching a peak in late March and early April. Even though steelhead usually seek out the smaller tributaries for spawning purposes, there is also a considerable amount of spawning at favorable sites in the main Trinity, Salmon, Scott, and Shasta Rivers.

Because of the recreational and economic value of the fishery to the Klamath River Basin and to the State, the over-all planning for development of water and other resources of the Basin is concerned not only with the preservation of the fishery at its present

level, but also with feasible improvement and enhancement of the fishery. The estimated minimum stream flows required to maintain the fishery at its present level may in some cases be slightly larger than those which occur at present. For an improved fish habitat, the major items required would include better spawning areas, reduction of rapid fluctuations in stream flow, increased flows, and cooler water temperatures during the late summer and early fall months. Preliminary estimates of minimum flows at certain points on the Klamath and Trinity Rivers required to maintain fish populations near their present levels, are presented in Tables 40 and 41.

The Klamath River Basin is traversed by the Pacific Migratory Waterfowl Flyway. This route, through which migratory waterfowl funnel on their annual flights from the breeding areas of western Canada to the winter feeding grounds of the southwestern states and Mexico, is centered in the vicinity of Klamath and Tule Lakes. The Fish and Wildlife Service of the United States Department of the Interior maintains three migratory waterfowl refuges in the Basin. These are the Tule Lake, Upper Klamath Lake, and Lower Klamath Lake Wildlife Refuges. They are so located as to provide convenient resting and feeding grounds for the birds on their flight southward. By providing feed to migratory water fowl at this stage of their flight, the depredation of rice and grain crops in the Central Valley by these birds is materially reduced.

During the period of fall waterfowl migration, commencing in late July and lasting until early December, lands in and surrounding the foregoing refuges are populated by up to four million waterfowl. This attraction during the hunting season draws people from throughout both California and Oregon to the Klamath River Basin. A 1955 survey by the California Department of Fish and Game indicated that 135,800 ducks and 62,600 geese were taken during that season in Siskiyou County.

Tule Lake and Lower Klamath refuges are located in Siskiyou County, and most of the ducks and geese bagged in that County are taken in the Klamath Basin. Based on data of the Fish and Wildlife Service, the Department of Fish and Game estimates that about $4,250,000 was spent by 70,860 duck and goose hunters in the Klamath River Basin during 1955.

Water in relatively large quantities is needed for the operation of migratory waterfowl refuges. It is used mainly for the flooding of grain fields for the production of feed, or for the replacement of water lost through evaporation from the water surfaces maintained for waterfowl. Both of these employments result in consumptive use of the water, and the water requirements for this purpose were evaluated in the preceding section of this bulletin.

Large primitive areas within the Klamath River Basin, such as the Trinity Alps and Marble Mountains, as well as the Lava Beds area of Modoc and Siskiyou Counties, provide habitat for an abundant amount of game such as deer and black bear. It has been estimated by the Department of Fish and Game that some 128,000 deer resided in the California portion of the Basin between 1947 and 1949. This figure is considered representative of the herd populating the Basin at the present time. Upland game birds and small mammals are also found in considerable quantity in various parts of the Basin.

Water requirements for such wildlife cannot be estimated with any degree of accuracy. However, it is known that such requirements are extremely small in comparison with those for other beneficial uses of water. The requirement is spread over such an extensive area that it can be met readily without specific

TABLE 40

ESTIMATED MINIMUM STREAM FLOWS AT SELECTED POINTS ON THE KLAMATH RIVER AND ITS TRIBUTARIES REQUIRED TO MAINTAIN GAME FISH POPULATIONS NEAR THEIR PRESENT LEVELS

(Estimates furnished by California Department of Fish and Game)

Stream	Location	Minimum flow, in second-feet: April through September	Minimum flow, in second-feet: October through March
Klamath River	At Klamath	1,200	2,000
Klamath River	Above confluence with Trinity River	650	1,200
Klamath River	Above confluence with Salmon River	500	1,000
Klamath River	Above confluence with Scott River	500	1,000
Klamath River	At confluence with Shasta River		
	Without daily fluctuation	1,000	1,000
	With daily fluctuation		
	High	1,500	
	Low	500	500
Salmon River	At confluence with Klamath River	150	300
Scott River	At confluence with Klamath River	100	250
Shasta River	At confluence with Klamath River	50	200
Trinity River	At confluence with Klamath River	250	1,000

TABLE 41

ESTIMATED MINIMUM STREAM FLOWS IN THE TRINITY RIVER BELOW LEWISTON REQUIRED TO MAINTAIN GAME FISH POPULATIONS NEAR THEIR PRESENT LEVELS

(Estimates furnished by California Department of Fish and Game)

Dates (all dates inclusive)	Minimum flow, in second-feet
October 1-October 31	200
November 1-November 30	250
December 1-December 31	200
January 1-September 30	150

development, from small streams, lakes, and springs, generally distributed throughout the area inhabited by wildlife.

The California portion of the Klamath River Basin produces about 27 per cent of the State's fur catch each year. The principal fur-bearing animals, in terms of numbers taken for pelts and cash returns to the trapper, are muskrat and mink. The Klamath River, from Copco Dam downstream, contains very little suitable muskrat habitat, but the upper drainage area with its adjacent sloughs, swamps, lakes, and waterways, is one of the leading producers of muskrat in California. The California Department of Fish and Game estimates that the fur catch during the 1955-56 season in Siskiyou and Trinity Counties had a value to trappers of $15,900.

The rugged, mountainous character of most of the Klamath River Basin, together with the forests, lakes, and flowing stream, make this region one of the finest recreational areas on the Pacific Coast. Scenic wonders, such as Crater Lake, Mt. Shasta, the Modoc Lava Beds, the Trinity Alps, and the Coast Redwoods are attractions responsible for bringing many tourists into the area.

The combined trade of tourists and sportsmen contributes appreciably to the economy of the Basin. As anticipated future technologic progress provides more leisure time for the people, it may be expected that the state-wide and national importance of such recreational areas will increase. As has been indicated, the recreational facilities afforded in the Basin depend to a great extent on the lakes, streams, and rivers contained therein. Although protection and preservation of these waters is necessary for the maintenance and improvement of the recreational development, no attempt was made to evaluate the water requirements for such purposes. These requirements are difficult to ascertain, and it was considered that they are included with, and are a part of those for other beneficial uses of water.

Requirements for Hydroelectric Power Production

One of the earliest hydroelectric power plants in northern California was established about 1892 on the Shasta River. This small plant was the forerunner of other installations constructed at various points throughout the Basin in the following years. In 1895, the first hydroelectric power plant on the Link River was built to serve Klamath Falls. Later, these small plants were combined into expanding electric utility companies and the companies, in turn, merged into larger public service agencies.

Today, the entire Basin is served by two such agencies, the California Oregon Power Company and the Pacific Gas and Electric Company. The California Oregon Power Company's service area includes the Oregon portion of the Klamath River Basin; all of Siskiyou, Modoc, and Del Norte Counties within the basin boundaries; plus a portion of the Trinity River watershed in the vicinity of Trinity Center. The Pacific Gas and Electric Company serves the remainder of the Trinity River watershed. An interconnection is maintained with the California Oregon Power Company, south of Dunsmuir.

There are seven public utility hydroelectric power installations within the Klamath River Basin at present. Six, operated by the California Oregon Power Company, are located on the Link and Klamath Rivers from Klamath Falls Oregon, downstream as far as Fall Creek, California. Their combined installed capacity is 133,000 kilowatts, and the total net generation in 1957 was about 400 million kilowatt-hours. The seventh plant, operated on the Trinity River by the Pacific Gas and Electric Company, has an installed capacity of 2,720 kilowatts.

Privately owned and operated power installations include three small diesel-electric plants, totaling 410 kilowatts of installed capacity; a 7,500-kilowatt steam-electric plant of the Weyerhaeuser Timber Company; and a 3,750-kilowatt steam-electric plant of the Long-Bell Lumber Company. The latter two plants are interconnected with the California Oregon Power Company system.

Data pertaining to the hydroelectric power plants in the Klamath River Basin are presented in Table 42, and locations of the plants are shown on Plate 2. Table 43 presents data on the use of water for generation of hydroelectric power at Copco Plants Nos. 1 and 2, for the seasons from 1949 through 1953. Recorded flows of the Klamath River below the hydroelectric power plants less flows recorded at Fall Creek, compared with recorded releases through the power plant turbines, indicate that nearly all available water of the Klamath River in this reach of the stream is utilized for the production of hydroelectric power.

The hydroelectric power potential of the Klamath River Basin has been studied by various agencies in the past. As early as 1928, Frank E. Bonner, then District Engineer of the United States Forest Service, reported on the power potential of the Basin, indicating that under ultimate development, with an installed capacity of approximately 1,290,000 kilowatts, a dependable capacity of about 778,000 kilowatts could be realized. Current hydroelectric power project proposals include works with an installed capacity of about 370,000 kilowatts in connection with the proposed Trinity River diversion project of the Bureau of Reclamation of the United States Department of the Interior.

The California Oregon Power Company completed construction in October, 1958, of an 80,000-kilowatt hydroelectric generating plant on the Klamath River at Big Bend, near Keno, Oregon. This plant is one of a series planned to completely develop the hydroelec-

tric power potential between upper Klamath Lake and Copco Lake.

The main Klamath River, from its confluence with the Shasta River to its mouth, is presently closed to any development by a "person, firm, corporation, or company," which would necessitate the construction of a dam or obstruction to the flow of the stream. This portion of the river was set aside by an initiative act, approved by the electorate of the State of California in 1924, which established the Klamath River Fish and Game District.

The expanding trend of the population and economy of the Klamath River Basin indicates an increasing requirement for electric power. Present indications are that future increased use of such power will come not only from an expanded domestic and agricultural requirement, but also from the requirements of the timber industry, as technologic progress makes new processes available for the development and utilization of this resource. It is probable that an increase in ground water pumping for irrigated agriculture will also add to the ultimate electric power requirement. In estimating this requirement for the Klamath River Basin under conditions of probable ultimate development, the assumption was made that all such power will be generated by hydroelectric installations. In this connection, it is presently indicated that fuel transportation problems will probably limit any large steam-electric or Diesel-electric installations to the coastal areas. However, the Pacific Gas and Electric Company has recently proposed an atomic powered electric plant to serve the Eureka area.

Information available on ground water occurrence in the Basin, and required data on ground water yields and average pumping lifts, are insufficient to permit an estimate of probable ultimate power requirement for development of ground water. Power demands for the irrigation pumping which may eventually be required in the Basin will principally be confined to the irrigation season from April through September.

TABLE 42

HYDROELECTRIC GENERATING PLANTS IN THE KLAMATH RIVER BASIN

Company and Plant	Stream	Head, in feet	Installed capacity, in kilowatts	1957 net generation, in thousands of kilowatt-hours
California Oregon Power Company				
Westside	Link River	48	775	6,600
Eastside	Link River	47	3,000	23,800
Keno [a]	Klamath River	27	750	870
Big Bend [b]	Klamath River	--------	80,000	----------
Copco No. 1	Klamath River	125	20,000	164,200
Copco No. 2	Klamath River	157	27,000	197,100
Fall Creek	Fall Creek	730	2,200	15,600
Pacific Gas and Electric Company				
Junction City	Trinity River	602	2,720	[c]8,800

[a] Keno hydroelectric generating plant retired from service May 17, 1957.
[b] Construction of Big Bend hydroelectric generating plant completed in October, 1958.
[c] Gross generation during 1956.

TABLE 43

DISCHARGE FROM CALIFORNIA OREGON POWER COMPANY HYDROELECTRIC PLANTS AT COPCO AND FLOW OF KLAMATH RIVER ABOVE FALL CREEK

(In 1,000 acre-feet)

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual totals
1949													
Copco No. 1	113.1	101.7	93.0	59.4	106.7	57.0	51.5	63.7	78.4	122.2	133.0	123.4	1,103.1
Copco No. 2	113.1	101.7	93.0	59.4	106.7	57.0	51.5	63.7	78.4	122.2	133.0	123.4	1,103.1
Klamath River above Fall Creek*	113.1	101.7	93.0	59.4	106.7	57.1	51.5	63.7	78.4	122.2	133.0	123.4	1,103.2
1950													
Copco No. 1	89.5	65.6	93.7	89.9	88.4	54.4	53.7	71.9	73.4	98.7	138.2	191.8	1,109.2
Copco No. 2	89.5	65.6	93.7	89.9	88.4	54.4	53.7	71.9	73.4	98.7	138.2	181.8	1,099.2
Klamath River above Fall Creek*	89.5	65.6	93.7	90.3	88.4	54.4	53.9	71.9	73.4	98.7	138.2	211.9	1,129.9
1951													
Copco No. 1	136.5	169.1	178.5	131.7	168.2	80.5	68.1	64.4	73.2	97.5	107.8	128.1	1,403.6
Copco No. 2	136.5	167.3	177.4	115.6	166.6	80.2	67.7	64.4	73.2	97.5	107.8	128.1	1,382.3
Klamath River above Fall Creek*	136.5	208.1	217.6	135.5	203.4	80.6	68.1	64.4	73.2	97.5	107.8	129.7	1,522.4
1952													
Copco No. 1	178.5	180.0	195.3	186.5	198.6	151.2	113.0	113.4	135.3	160.1	142.7	141.9	1,896.5
Copco No. 2	178.5	179.5	194.6	174.5	150.3	129.5	113.0	92.7	125.1	159.6	142.0	141.9	1,781.2
Klamath River above Fall Creek*	183.9	224.8	278.1	381.0	291.7	156.8	114.2	116.3	136.3	159.0	140.4	138.3	2,320.8
1953													
Copco No. 1	172.7	175.5	197.5	180.0	194.4	166.6	111.8	117.0	151.6	162.3	171.8	156.8	1,958.0
Copco No. 2	164.7	143.5	188.4	159.1	136.6	120.5	111.5	116.8	151.6	161.9	171.8	156.8	1,783.2
Klamath River above Fall Creek*	172.0	288.1	236.7	179.2	268.8	227.6	108.5	116.6	152.5	161.3	172.2	153.5	2,237.0

* Flow of Klamath River above Fall Creek computed by subtracting the recorded flow of Fall Creek at Copco from recorded flow of Klamath River near Copco (below Fall Creek).

Study of the mining industry indicates that, even under maximum probable development of the Basin's mineral potential, the processes of smelting and refining will probably be largely carried on outside the basin boundaries. Production of ore, or quarrying of nonmetallic minerals, while having a power requirement, will not involve a large energy demand as compared to other probable requirements for power, such as that for development of the timber resource. Any future demands for electric power for mining purposes should be fairly constant throughout the year.

The estimate of the electric power requirement for the timber industry, under conditions of probable ultimate development, was based upon the assumption of full sustained utilization of the available timber resource for sawed lumber or for manufactured products. Wastes from lumber production were assumed to be used in other processes such as pulp or hardboard manufacturing, and not as fuel for power generation. Under this assumption the full need for power by the timber industry would be met by hydroelectric generation, and the estimated ultimate electric power requirement would necessitate an installed capacity of approximately 150,000 kilowatts. Such an ultimate timber industry would have a fairly uniform monthly power demand throughout the year.

The estimate of the domestic electric power requirement, both rural and urban, under conditions of probable ultimate development, was based upon a forecast ultimate basin population of about 180,000 persons. Allowing for increased per capita domestic use of electricity stemming from the further development of home appliances and labor-saving devices, it was estimated that power consumption by domestic users may ultimately require an installed capacity of approximately 30,000 kilowatts. The monthly power demand by such users tends to increase slightly in the winter due to use of electricity for heating purposes.

In summary, it was estimated that the ultimate power requirements of the Klamath River Basin will be in the order of 200,000 kilowatts of installed capacity. It is impracticable to estimate at this time the quantity of water required to develop this power.

TABLE 44

MONTHLY ELECTRICAL ENERGY DEMANDS OF NORTHERN CALIFORNIA POWER LOAD AS ESTIMATED FOR 1960

(In percent of total annual kilowatt-hours)

Month	Per cent	Month	Per cent
January	7.71	July	9.61
February	7.19	August	9.67
March	8.25	September	8.41
April	8.07	October	8.24
May	8.24	November	7.69
June	8.89	December	8.03

The available head, regimen of stream flows, and the physical conditions controlling plans for development will influence and establish the requirement for water.

Table 44 presents an estimate of the monthly distribution, in per cent of annual electrical energy demands, of power requirements in northern California, for the year 1960. These estimates were prepared by the California Public Utilities Commission and published in their special study No. S-1361 in October 1957. They are considered to be representative of electric power demands in the Klamath River Basin.

Requirements for the Mining Industry

Discovery of gold in northern California in 1848 caused the initial influx of people which led to permanent settlement and development of the area. Over the passing years the production of minerals has been of varying importance to the local economy. Metallic minerals, such as gold, copper, and chromite, are found in commercial quantities in the southern and western portions of the Klamath River Basin. Nonmetallic minerals, such as pumice and diatomaceous earth, are found mainly in Oregon and in the eastern portions of the Basin, while commercial development of sand, gravel, and building stone has been general throughout the Basin.

Until the beginning of World War II, gold mining was actively pursued in Trinity and Siskiyou Counties. War-time restrictions caused a virtual shutdown of this industry, and its subsequent recovery has been slow. In 1948, gold production in the Klamath River Basin was an estimated 29,000 ounces, worth a little more than $1,000,000. This gold was taken from 15 lode and 49 placer properties. Water usage was heaviest for the placer mining industry, where hydraulic and dredging methods were used. Available estimates of the water required for the 1948 gold production range from 37,000 to 40,000 acre-feet. Very little of this water was used consumptively, the greater portion being returned to stream channels where it was available for re-use. The restrictions now placed on hydraulic mining and gold dredging, to prevent stream pollution and destruction of land, indicate that gold will be produced by less destructive methods in the future and that smaller amounts of water will be required. The milling of gold ore from mines requires very little water for processing, and most of this water becomes available for re-use.

Copper mining in the western portion of the Klamath River Basin was stimulated by the demands of World War II, and during the war, one deposit in Siskiyou County was the largest producer of copper ore in California. However, at the present time the development of copper deposits is at a standstill. Chromite is another mineral found in relatively small deposits through the western portion of the Basin, production of which was stimulated during the war years, with subsequent recession. Silver is found

chiefly as a by-product of gold and copper mining. Water requirements for the mining and reduction of ores of these minerals are negligible.

Sands and gravels are found in commercial quantities at many locations throughout the Klamath River Basin. Available estimates indicate that 1948 sand and gravel production was about 382,000 tons. The water requirement for this industry, mostly for use in washing, was estimated to be about one acre-foot for every 440 tons of sand and gravel produced. Using this figure, the 1948 production of sand and gravel required less than 1,000 acre-feet of water, most of which became available for re-use. Even though future production of these materials increases greatly from present levels, the water requirement will be negligible as compared to other water requirements of the Basin.

Building stone production, occurring mostly in the southwestern half of the Klamath River Basin, was in the neighborhood of 200,000 tons in 1948. The quarrying, however, required practically no water. Possible increased production of this commodity in the future will have little effect on water requirements. Pumice and diatomaceous earth are produced in large quantities in the northeastern portion of the Basin, and there are vast reserves of these minerals available. However, the amount of water used in mining these minerals is negligible.

There are no facilities for refining any of the foregoing metallic minerals in the Klamath River Basin. Some reduction and concentration of ores is performed at the source, but these concentrates are exported for final processing. However, even should ore refineries be established locally, the water requirement of such an industry would be relatively small. Refining of gold, chromite, copper, and silver ores requires only minor amounts of water.

Based upon present production of minerals in the Klamath River Basin, gold has the highest water requirement and the only one of significance. It is estimated that 50,000 acre-feet of water seasonally will satisfy the maximum present needs of this industry. It is probable that future gold production, though it may increase considerably over the present volume, will require very little additional water, due to anticipated changes in mining methods. It is estimated that an additional 10,000 acre-feet of water seasonally, will provide for present as well as future increased production of sand and gravel and other miscellaneous mining. The probable ultimate water requirement of the mining industry in the Basin would then be about 60,000 acre-feet per season. Practically all of this estimated requirement would be nonconsumptive in nature, and the return flow would be available for re-use downstream.

Requirements for the Timber Industry

Since 1930, the States of Oregon, Washington, and California have been the leading lumber producers in the Nation, and Oregon and California rank first and second in this respect at present (1955). The California portion of the Klamath River Basin produces about 20 per cent of the total lumber output of the State, and the Basin as a whole accounts for from four to five per cent of the total national production. Furthermore, the largest remaining volume of saw timber, and a large portion of the finest timber cropland in the United States are contained in the Klamath River Basin and southwestern Oregon.

At present the timber industry leads the Klamath River Basin in terms of value of product, industrial payroll, and personal income produced. Production of wood products is the only manufacturing industry of significance in the Basin. Nearly 40 per cent of the total labor force is employed in the timber industry, compared to about 10 per cent in agriculture, and the value of timber and timber products is almost three times the value of agricultural products. About 7,500 workers are employed in the timber industry, and some 80 per cent of the present population of the Basin is dependent, directly or indirectly, on this activity.

Of the total area within the Klamath River Basin, about 45 per cent is available for continuous commercial timber production. An additional 30 per cent of the area is either in forest land reserved for parks and primitive areas, watershed protection, and other uses. Approximately two-thirds of the available timber cropland is in public ownership.

Approximately 250,000,000 board feet of timber is being logged annually from National Forest, Indian Service, and other public lands in the Klamath River Basin. Complete data on production from private lands are difficult to obtain, but indications are that production on private lands amounts to one and one-half times that on the public lands. Before World War II most of the logs produced in the Basin were exported for processing.

The timber industry has developed in a different fashion in the southwestern half of the Klamath River Basin than it did in the northeastern half. In the northeastern half, embracing that portion east of the Cascade Range, development was characterized first by early scattered operations, then by rapid expansion, and finally by overdevelopment of mill capacity in relation to available sustained yield production. Production has now receded because of dwindling timber resources, and has leveled off at the point where mill capacity does not greatly exceed annual timber replenishment. In the southwestern half of the Basin, south and west of the Cascade Range, the timber industry is still in relative infancy. Operations are fairly scattered and a large portion of the timber resources is as yet untouched, present production amounting to only a fraction of the sustained yield potential.

Lumber Mill on Lake Ewana at Klamath Falls, Oregon

Klamath County Chamber of Commerce photograph

Lumber stacked for air drying

Klamath County Chamber of Commerce photograph

In the northeastern half of the Klamath River Basin the recession in timber production has been accompanied by a trend toward greater integration of operations and greater diversity in manufacture of wood products. On most National Forest lands in this region cutting is already at sustained yield capacity. Most of the private lands have been cut over, but operations have been reduced so that a fairly stable level of timber production has been achieved in Klamath and Modoc Counties. Although there is still some mill capacity in excess of the sustained yield volume of the present stands of timber, further contraction of the industry probably will be prevented by further processing of the timber, and better use of heretofore undesirable species along with wood wastes and mill residues.

In the southwestern half of the Klamath River Basin, timber production currently is about one-third of the sustained yield potential. Rugged terrain, inaccessible timber, and lack of transportation have retarded development. However, the high post-war demand for timber has increased the rate of development considerably. In Trinity County, timber production increased from 903,000 board feet in 1940 to over 200,000,000 board feet in 1953. Over 70 per cent of the timber cropland in this portion of the Basin is in public ownership, which would indicate that over-expansion of production capacity in relation to sustained yield is not likely to occur.

It has been estimated that under competent forest management the timber lands of the Klamath River Basin can be brought up to an optimum sustained yield production of 1,300,000,000 board feet of logs annually, or about twice the present production. Of this total, about 60 per cent will probably be processed within the basin boundaries. It is estimated that, including material that will be available from thinning operations, tree bark, and salvaged logging and mill wastes, an equivalent volume of between 1,100,000,000 and 1,200,000,000 board feet of logs will be processed.

The change in the nature of the timber industry, from straight sawmill operations to manufacture of diversified products such as plywood, hardboard, fiberboard, and other articles in addition to lumber, is following the pattern which has been established by the industry in the Pacific northwest. It is believed that the industry, as it moves toward more complete use of the timber resource, will continue to follow the pattern established in the northwest, with ultimate manufacture of additional wood products such as pulp and paper in or adjacent to the Basin.

In connection with the foregoing, available data from the United States Forest Service, technical bulletins, journals of the timber industry, and records of production from mills of the Pacific northwest, indicate that in the future the cull timber, logging wastes, and mill wastes of the Klamath River Basin probably will be used for manufacture of such products as pulp, paper, hardboard, and fiberboard. From these data it was estimated that under ultimate conditions as much as 10 per cent of the total volume of logs cut, or from 110,000,000 to 120,000,000 board feet annually, may be turned into chips which would be available for pulp production.

The water requirement for the sulfate process of making pulp, best adapted to use of coniferous woods such as pine, fir, and spruce that prevail in the Basin, averages about 60,000 gallons per ton of chips. Use of 120,000,000 board feet of timber annually for pulp would require about 24,000 acre-feet of water for processing. For the most part such water would not be consumptively used, but the effluent would be so highly acidic, with a high biochemical oxygen demand, as to require treatment before returning to the stream, to prevent obnoxious pollution and destruction of fish life.

To produce pulp by the sulfate process, the recovery of chemicals from the processing water has been shown to be necessary. However, the waste waters contain chemicals which have a very obnoxious odor and are apparently toxic to fish life, even in very small concentrations. It is doubtful whether existing laws would permit injection of such pollutants into streams of the Klamath River Basin since, even under conditions of extreme dilution, the wastes would probably tend to degrade the fish habitat and impair recreational values. Disposal of the wastes by other means, such as evaporation or pondage is possible, but its practical application would depend upon economic considerations.

As has been stated, most studies indicate that manufacture of pulp and paper from cull timber and logging and mill wastes of the Klamath River Basin will probably occur on tidewater and outside the boundaries of the Basin. This conclusion has been supported by the possibility of ocean diffusion of wastes from the manufacturing process and the availability of low-cost water transportation for delivering pulp and paper to market areas. In view of present methods of pulp and paper manufacturing, laws pertaining to water pollution, and transportation opportunities, such conclusions seem valid. This indicates that pulp and paper production probably will not become a significant part of the timber industry within the boundaries of the Klamath River Basin. It is, however, considered probable that these industries may be established on the coast to process material from within the Basin. This would impose water requirement equivalent in quantity to that previously computed.

In order to evaluate the probable future nonconsumptive requirement for water by the timber industry in the Klamath River Basin, it was assumed the previously computed 24,000 acre-feet per season for wood products processing would be furnished from streams in the Basin. This requirement is likely to occur in the lower reaches of the stream system, where

re-use of the water would not be practicable. It was assumed that an additional 6,000 acre-feet of water per season would be required for maintaining log ponds, and other miscellaneous uses in sawmill operation. An estimated total of 30,000 acre-feet of water per season would therefore be required for the timber industry in the Klamath River Basin under conditions of ultimate development.

Flood Control Considerations

Damage from floods in the Klamath River Basin has been confined to relatively small areas, and the aggregate monetary loss, except from the disastrous flood which devastated the town of Klamath in December 1955, has not been large. Those areas suffering recent flood damage are Butte Valley, Scott Valley, portions of Shasta Valley, and the low-lying lands at the mouth of the Klamath River.

Damage in the upper valleys has resulted mainly from loss of land by erosion, and from destruction of bridges and other structures. Losses at the mouth of the Klamath River included destruction of roadways, homes and businesses, pollution of domestic water supplies, and general damage to most property within the low-lying areas.

A serious local flood problem has been created in Butte Valley by the accumulation of water in Meiss Lake over the period of wet years from 1955 to 1958. About 4,500 acres of land, once reclaimed, has been covered over by Meiss Lake. Problems of drainage into Meiss Lake have also been created.

Prevention of loss of land by erosion could be accomplished to a large extent by channel improvement works. Construction of storage reservoirs, either on the Klamath River or its tributaries, would have a tendency to decrease flood damage at all points downstream from the reservoirs. However, in view of the magnitude of the 1955 flood, nearly twice the previously recorded maximum, a comprehensive investigation of flood conditions is needed to recommend an adequate solution to the problem.

Peak flood runoff is largely unavailable for other purposes, and usually results in a loss to the available water supply. However, storage dedicated to the control of snow melt floods can generally be used for conservation purposes, after the danger of seasonal floods is lessened.

SUPPLEMENTAL WATER REQUIREMENTS

The data, analyses, and estimates of water supply and utilization in the Klamath River Basin indicate that present supplemental requirements for irrigated agriculture and the attendant urban and miscellaneous water uses are small in quantity and restricted to localized areas and conditions. Ultimate supplemental requirements, on the other hand, can only be provided for by additional development and distribution of presently unregulated surface supplies and by ground water development. The Shasta and Scott Rivers provide potential sources of water, but the Klamath River remains the principal source of new water for much of the undeveloped land within the California portion of the Basin.

Discussions of present and ultimate supplemental water requirements contained in this section are confined to those hydrographic units in California containing the largest areas of land requiring water service—the Oklahoma District, Butte Valley, Shasta Valley, and Scott Valley. Other portions of the Basin, along the Salmon, Trinity, and Klamath Rivers, contain relatively small non-contiguous stringers of land.

The evaluation of present supplemental water requirements for areas served by surface storage was based on present land development and water needs as compared with the safe yield of surface storage, with due allowance for the ability of the agricultural economy to absorb a deficiency in supply in exceptionally dry years. In agricultural areas where the source of supply is the unregulated natural regimen of streams, present supplemental requirements were evaluated from records and estimates of stream flow and diversion compared to estimates of water requirements. Analysis of the existing availability of water in such areas resulted in the conclusion that there is no present supplemental water requirement except in occasional dry years. The adequacy of developed water supplies is discussed under Present Supplemental Requirements.

Estimates of probable ultimate supplemental requirements were related to the development of new irrigated land, industries, and urban areas, as well as to the need for a firm and dependable water supply for those presently irrigated lands experiencing seasonal shortages. The estimates of probable ultimate requirements for supplemental water were computed as the difference between estimated present and ultimate requirements.

Present Supplemental Requirements

A large part of the irrigation development in the California portion of the Klamath River Basin is by diversion of unregulated surface supplies. There are two exceptions to this general rule, one in Butte Valley where ground water is pumped, and the other in Shasta Valley where Dwinnell Reservoir is utilized for storage and regulation of the Shasta River. Thus, most irrigated lands have an ample water supply during the spring months of April, May, and June, but only those with higher priority water rights are assured of a full supply throughout the irrigation season. Agricultural practice in the Basin has therefore necessarily been adapted to this natural variation in seasonal water supply.

The present requirement for supplemental water in Butte Valley was evaluated as the difference be-

tween safe yield of the ground water basin and present consumptive use of ground water. Items of the hydrologic balance have been previously discussed in Chapter II, Water Supply, and are set forth in Table 15. The present irrigated land in Butte Valley Subunit 5, Macdoel, utilizes ground water withdrawals as a principal source of water supply. Therefore, the aforementioned criteria for evaluating safe yield of ground water basins were considered. Data available from studies of the United States Bureau of Reclamation and United States Geological Survey, as well as a hydrologic analysis of the ground water basin, indicated that the present water applied on irrigated and urban lands is about 27,000 acre-feet, seasonally, of which about 12,000 acre-feet is consumptively used. The studies further indicated that the present seasonal consumptive use of applied water in the Macdoel Subunit, for both beneficial uses and evaporation from water surfaces, is approximately equivalent to the safe yield of the combined surface and ground water supply. The water supply is apparently satisfactory in quantity, on the average, for the present level of development. This indicates that there was no present supplemental requirement for water for lands irrigated in Butte Valley at the time this survey was made.

Irrigation supplies for Shasta Valley are presently provided by storage in Dwinnell Reservoir, by diversion from unregulated streamflow, and by a small amount of ground water pumping. The available water supply and requirements of each of the subunits were individually analyzed and compared. Following are some pertinent comments regarding each of the subunits.

The present water requirements of Subunit 6A, Yreka, are about 2,000 acre-feet seasonally, of which more than half is used for municipal and industrial needs. Yreka's municipal water supply system has experienced deficiencies in quantity and quality during critical portions of recent years, indicating a need for an additional dependable supply. Municipal water supplies must be adequate to meet, without deficiency, present as well as growing demands during the most critical periods. Consequently, a present supplemental requirement exists in this subunit. The City of Yreka has undertaken construction of a dam and reservoir on Greenhorn Creek to provide an additional 650 acre-feet per season.

Operation studies of Dwinnell Reservoir through a critical series of dry years, utilizing the present allowable storage capacity of 50,000 acre-feet, indicate that the firm seasonal yield of the reservoir would be about 21,500 acre-feet during normal years but would drop as low as 12,000 acre-feet during 1923-24, the driest year on record. The yield of the reservoir would be very close to the present demand during the dry years 1930-31 and 1933-34. Water supplies from Dwinnell Reservoir, therefore, normally satisfy the service area requirements and are only occasionally deficient in quantity.

Water supplies available during a normal period to lands in Subunit 6B from the Little Shasta and Shasta Rivers aggregate about 34,000 acre-feet for the irrigation season. This quantity exceeds the estimated requirement of approximately 16,000 acre-feet, indicating an adequate water supply for the present requirement. The availability of supply and requirements for use in Subunit 6B indicates that, although occasional deficiencies occur in supply from Dwinnell Reservoir, and in the late season from Little Shasta River, the unit as a whole has an adequate water supply to meet present requirements.

Water supplies from Shasta River, Willow Creek, and to a limited extent from ground water, serve the lands in Subunit 6C, Gazelle-Grenada. A summary of average diversions during the irrigation season shows that about 28,000 acre-feet are diverted from all sources. This amount approximates the estimated present requirement for water, indicating that water supplies are adequate in this unit to serve presently developed lands.

Subunit 6D, Big Springs-Juniper, comprises lands served from Big Springs and from ground water. The firm yield of both sources is adequate to meet the requirements of presently developed irrigated lands.

Subunit 6F, Parks Creek, has an estimated present requirement for water of 10,000 acre-feet seasonally. Water supplies originate in Parks Creek and are supplemented to some extent by springs. A summary of average water supply available to meet these requirements indicates an adequate quantity, although during years of low flow deficiencies occur in the late summer months.

Subunit 6G, Upper Shasta, is served by diversions from Shasta River and importation of about 4,000 acre-feet per season from the Sacramento River watershed. These lands, like others throughout the valley, receive an adequate water supply during normal years, but experience late summer shortages in years of deficient runoff.

Water supplies available to lands in Scott Valley are in all instances dependent upon the natural regimen of stream flow. Deficiencies usually occur in late summer and fall as the snowmelt stream flows fail. Estimates of the quantity of the water supply deficiency would require an analysis of water available for irrigation diversion during the low flow months. As sufficient data were not available, no quantitative analysis was made of the present deficiency. These deficiencies become more pronounced in years of subnormal water supply, and are reflected in the economy by a lowering of crop yields.

Table 45 presents data concerning the estimated present and ultimate water requirements and, where

applicable, supplemental water requirements in the Klamath River Basin in California.

Ultimate Supplemental Requirements

The probable ultimate requirement for supplemental water in the Klamath River Basin in California was evaluated as the difference between the present and probable ultimate average seasonal requirement for water supplies. Development and utilization of supplemental water supplies in the quantities estimated would, it is believed, assure an adequate supply to both lands presently irrigated within the Basin and those irrigable lands not presently served with water. The estimates of quantities of water required are presented in Table 45.

Probable Future Change in Flow of Klamath River

Changes in the availability and regime of water supplies may result from changes in the water use and land use patterns in individual areas. For example, the reclamation of a marsh into well managed irrigated pasture may cause a decrease in consumptive use of water and an increase in the water supply available for other purposes. Conversely, a change in agricultural practice from grain production to irrigated pasture may result in greater consumptive use of water on the particular area and a decrease in the water supply available for other purposes. In general, as native lands are brought under irrigation, the regimen of downstream flows is influenced and changed. For the most part, the amount of the change is measured by the difference in consumptive use of water and irrecoverable losses between any two stages of development.

One objective of the current investigation was to evaluate the probable future change in surface flow of the Klamath River at the California-Oregon State line and downstream from the Shasta River. Inasmuch as the Klamath River is an interstate stream, plans for future development in the lower basin and elsewhere in California, that are dependent upon this source as a firm water supply, can anticipate the availability of only those flows remaining in the river after complete land development and water utilization in the upper basin. Studies of future flow of the Klamath River require adjustment of the historical flow in accordance with assumed conditions of development. Certain terms relating to stream flow, as utilized in these studies, are defined at the beginning of Chapter II.

Estimates of natural flow of the Klamath River at Keno and points downstream for the period from 1894-95 through 1946-47 were previously computed and published in State Water Resources Board Bulletin No. 1, "Water Resources of California." The estimates presented in Bulletin No. 1 represent total runoff from stream basin areas. Therefore, in the case of the Klamath River at Keno the estimated flows are not natural flows of the Klamath River, since the runoff of Lost River and streams tributary to Butte Valley enter closed basins under natural conditions. For this investigation, flows into the closed basins were excluded from the estimates of natural flow of the Klamath River.

The present impaired flow of the Klamath River at Keno was estimated for the 32-year period, 1920-21 through 1951-52, by means of a monthly operation study, taking into account existing water supply demands, losses, and return flows above Keno. The basic data and criteria for this study were originally compiled for the period from 1927-28 through 1946-47 by the United States Bureau of Reclamation, and were extended by the Department of Water Resources to include the longer period.

Since irrigation development in the area above Upper Klamath Lake was equivalent to present conditions during the 32-year period, the recorded inflow to Upper Klamath Lake was used without modification. Irrigation demands on Upper Klamath Lake and Lost River, to meet the Klamath Project needs, were

TABLE 45

ESTIMATED PRESENT AND PROBABLE ULTIMATE MEAN SEASONAL SUPPLEMENTAL WATER REQUIREMENTS WITHIN HYDROGRAPHIC UNITS IN THE KLAMATH RIVER BASIN

(In acre-feet)

Hydrographic unit and subunit				Supplemental water requirements	
Reference number	Name	Present water requirement	Ultimate water requirement	Present	Ultimate
4E	Oklahoma	31,000	82,000	0	51,000
5	Butte Valley				
5A	Macdoel	34,000	101,000	0	67,000
5B	Butte Creek	10,000	42,000	0	32,000
5C	Red Rock	0	21,000	0	21,000
	Subtotal				120,000
6	Shasta Valley				
6A	Yreka	2,000	24,000	0	22,000
6B	Little Shasta	32,000	105,000	0	73,000
6C	Gazelle-Grenada	27,000	107,000	0	80,000
6D	Big Springs-Juniper	15,000	52,000	0	37,000
6E	Grass Lake	5,000	9,000	0	4,000
6F	Parks Creek	10,000	30,000	0	20,000
6G	Upper Shasta	16,000	54,000	0	38,000
	Subtotal				274,000
7	Scott Valley				
7A	East Side	21,000	44,000	0	23,000
7B	Moffett Creek	4,000	13,000	0	9,000
7C	Quartz Valley	12,000	27,000	0	15,000
7D	West Side	40,000	56,000	0	16,000
7E	Callahan	10,000	20,000	0	10,000
	Subtotal				73,000

estimated to be 418,000 acre-feet, seasonally. Results of the study indicated that the average seasonal present impaired flow of the Klamath River at Keno for the 32-year period is 870,000 acre-feet.

The probable seasonal ultimate impaired flow of the Klamath River at Keno was estimated by means of an operation study of the Klamath River System above Keno under ultimate conditions of development. A seasonal summary of this study is presented in Appendix E. The following conditions were assumed to exist with ultimate development:

(a) Above Upper Klamath Lake all irrigable lands would be irrigated. Swamp and marsh lands would exist as shown in Table 26. Beatty Reservoir on the Sprague River would be constructed with a storage capacity of 150,000 acre-feet.

(b) Braymill Reservoir on the Sprague River would be constructed with a storage capacity of about 440,000 acre-feet, as an alternative to providing additional storage in Upper Klamath Lake. The latter would continue to be operated within its present active capacity of 483,000 acre-feet.

(c) The water conservation functions of Clear Lake Reservoir on Lost River would be replaced by Boundary Reservoir.

(d) The ultimate irrigation demand from the Upper Klamath River and Lost River systems would equal the present demand of the Klamath Project, 418,000 acre-feet annually, as established by the Bureau of Reclamation, plus an additional 100,000 acre-feet for development of extensions to the project. Demands on Upper Klamath Lake to meet the ultimate supplemental water requirements of the Oklahoma, Macdoel, Butte Creek, and Red Rock Subunits would be 200,000 acre-feet annually. Return flows from these subunits would discharge to the Klamath River above Keno.

TABLE 46

HISTORICAL AND ESTIMATED SEASONAL FLOWS OF THE KLAMATH RIVER AT KENO UNDER NATURAL, HISTORICAL, PRESENT IMPAIRED, AND PROBABLE ULTIMATE IMPAIRED CONDITIONS
1920-21 to 1951-52

(In 1,000 acre-feet)

Season	Natural	Recorded historical	Present impaired	Probable ultimate impaired
1920-21	1,681	1,660	1,647	683
1921-22	1,367	1,410	1,134	585
1922-23	1,171	1,150	931	419
1923-24	940	868	600	223
1924-25	1,312	1,120	796	319
1925-26	860	840	631	262
1926-27	1,472	1,300	1,057	302
1927-28	1,251	1,230	806	368
1928-29	925	802	610	310
1929-30	890	648	511	277
1930-31	705	395	420	260
1931-32	865	514	443	276
1932-33	840	515	430	267
1933-34	750	547	430	251
1934-35	945	650	520	285
1935-36	1,081	884	781	328
1936-37	920	686	566	292
1937-38	1,547	1,492	1,411	737
1938-39	945	744	621	348
1939-40	1,181	987	944	534
1940-41	1,021	782	656	337
1941-42	1,166	1,038	946	525
1942-43	1,838	1,747	1,618	1,257
1943-44	1,081	959	789	534
1944-45	1,101	910	790	369
1945-46	1,372	1,154	1,097	696
1946-47	997	732	720	390
1947-48	1,104	824	765	372
1948-49	1,136	902	941	384
1949-50	1,201	902	892	549
1950-51	1,680	1,444	1,506	1,175
1951-52	2,137	1,919	1,790	1,682
Mean for period	1,170	990	870	487

TABLE 47

ESTIMATED SEASONAL FLOWS OF THE KLAMATH RIVER BELOW SHASTA RIVER UNDER NATURAL, HISTORICAL, PRESENT IMPAIRED, AND PROBABLE ULTIMATE IMPAIRED CONDITIONS
1920-21 to 1951-52

(In 1,000 acre-feet)

Season	Natural	Estimated historical	Present impaired	Probable ultimate impaired
1920-21	2,435	--	2,376	1,132
1921-22	1,931	--	1,649	950
1922-23	1,677	--	1,390	727
1923-24	1,443	1,282	1,068	547
1924-25	1,918	1,585	1,332	667
1925-26	1,403	1,286	1,127	618
1926-27	2,227	1,925	1,751	824
1927-28	1,852	1,701	1,358	787
1928-29	1,433	1,192	1,053	605
1929-30	1,413	1,072	976	577
1930-31	1,080	723	744	433
1931-32	1,431	1,025	948	620
1932-33	1,437	1,051	964	641
1933-34	1,188	921	802	473
1934-35	1,495	1,142	1,007	616
1935-36	1,680	1,428	1,318	708
1936-37	1,475	1,180	1,056	620
1937-38	2,509	2,405	2,321	1,453
1938-39	1,422	1,180	1,050	658
1939-40	1,862	1,619	1,572	969
1940-41	1,745	1,447	1,319	814
1941-42	1,834	1,704	1,605	1,014
1942-43	2,428	2,327	2,193	1,628
1943-44	1,570	1,416	1,242	809
1944-45	1,699	1,426	1,301	738
1945-46	2,084	1,789	1,743	1,183
1946-47	1,470	1,133	1,120	638
1947-48	1,786	1,416	1,357	779
1948-49	1,706	1,401	1,439	731
1949-50	1,823	1,449	1,438	942
1950-51	2,549	2,231	2,293	1,801
1951-52	3,068	2,758	2,759	2,340
Mean for period	1,780	1,490	1,430	876

(e) Releases from Upper Klamath Lake available for production of hydroelectric power would be limited to an average of about 200,000 acre-feet annually.

Table 46 presents estimates of the seasonal flows of the Klamath River at Keno for the 32-year period, under present and probable ultimate conditions of development. The recorded historical and estimated natural flows of the river are also listed.

In the course of this investigation it was determined that a portion of the ultimate supplemental water requirements for Shasta Valley would logically be diverted from the Klamath River. Estimates of the change in flow of the Klamath River below the Shasta River, as a result of future development above that point, were made to show the flows remaining for possible development in the Basin below the confluence of the two streams. These estimates were based on present and ultimate impaired flows at Keno, plus accretions, and minus future diversions between Keno and the Shasta River.

Table 47 presents estimates of the seasonal flows of the Klamath River below Shasta River for the period from 1920-21 through 1951-52, under present and probable ultimate conditions of development. Also shown in the table are natural and recorded flows of the Klamath River at the same location.

CHAPTER IV

PLANS FOR WATER DEVELOPMENT

The inventory of water resources and the analysis of water needs show that the water supply of the Klamath River Basin greatly exceeds the probable ultimate water requirement. This situation exists primarily in the portion of the Klamath River Basin downstream from the mouth of the Shasta River, and in the Trinity River Basin. However, in some areas, Shasta Valley and Butte Valley particularly, the locally available water supplies are insufficient to meet ultimate requirements. In other areas, including Scott Valley and the Upper Klamath River Basin in Oregon, local water supplies are adequate for probable ultimate development, but the construction of storage works would be necessary to conserve and regulate the available water. Recognizing that the Klamath River constitutes a principal source of water for export to water-deficient areas elsewhere in California, plans for water development presented in this chapter follow the intent of The California Water Plan by giving full consideration to the needs of the upper basins.

This chapter presents the features of The California Water Plan that would be required for the control, development, conservation, and utilization of the water resources of the Klamath River Basin. Following a brief introduction to the statewide aspects of The California Water Plan, this chapter presents plans for development of water supplies for local use within the basin. Also presented is a summary of the features of the California Aqueduct System comprising works required to export surplus waters from the Klamath and Trinity Rivers into the Sacramento Valley. Projects discussed herein are shown on Plate 16, "Features of The California Water Plan Within the Klamath River Basin."

THE CALIFORNIA WATER PLAN

From 1947 to 1956 the Department (formerly Division) of Water Resources conducted the State-wide Water Resources Investigation, with the objective of formulating a long-range plan for comprehensive development of the water resources of California. The results comprise "The California Water Plan."

The first phase of the investigation consisted of an inventory of available data on sources, quantities, and characteristics of water in California. State Water Resources Board Bulletin No. 1, "Water Resources of California," published in 1951, contains a concise compilation of available data on precipitation, runoff of streams, flood flows and frequencies, and quality of water throughout the State.

The second phase dealt with present and ultimate requirements for water. Results of this study are presented in State Water Resources Board Bulletin No. 2, "Water Utilization and Requirements of California," 1955. This bulletin includes determinations of the present use of water throughout the State for all consumptive purposes, and presents forecasts of ultimate water requirements based, in general, on the capabilities of the land to support further development. Bulletin No. 2 also discusses the implications of nonconsumptive requirements for water as they relate to planning for the future.

The third and final phase of this planning program proceeded concurrently with the foregoing studies. This phase included the surveys and definitive studies for The California Water Plan. The results are presented in Department of Water Resources Bulletin No. 3, "The California Water Plan," May, 1957.

The estimated mean seasonal natural runoff of California streams is about 71,000,000 acre-feet. The greatest contribution comes from streams of the North Coastal Area, which together furnish about 41 per cent of the total runoff for the State, and from streams of the Sacramento River Basin in the Central Valley Area, which furnish about 32 per cent. Most of the remainder of the natural water supplies, some 16 per cent of the State's total, originates in the San Joaquin Valley, while the rest of the State produces only relatively small amounts of runoff.

By far the largest use of water in California is for agriculture, a condition that will prevail even under conditions of ultimate development. The requirement for water for irrigated agriculture for the entire State, about 19,100,000 acre-feet per season in 1950, should nearly double under conditions of complete development to more than 41,000,000 acre-feet. It is anticipated that in the future the total ultimate requirement for water for all urban and miscellaneous purposes will increase about five-fold from the present 2,000,000 acre-feet per season to about 10,000,000 acre-feet per season. The total water requirements for all purposes in California as of 1950 were about 21,-100,000 acre-feet per season, and the forecast ultimate seasonal use is some 51,100,000 acre-feet.

A geographical breakdown, and comparison of the ultimate requirement forecast with the occurrence of runoff, indicates that the Central Valley Area, with 48 per cent of the runoff, should ultimately require almost 53 per cent of the developed water supplies. However, more than two-thirds of this ultimate use should be in the water-deficient San Joaquin Valley.

The North Coastal Area with its great natural water supply, 41 per cent of the total in the State, should ultimately require only about 5 per cent of the water consumptively used throughout California.

It is forecast that the San Francisco Bay Area and the South Coastal Area, with their tremendous metropolitan developments, will need about 7 and 12 per cent, respectively, of the ultimate developed water supply. Between them they enjoy 3.5 per cent of the natural water supply. The Central Coastal Area will ultimately require about 5 per cent of the developed water supply, and the extremely arid Lahontan and Colorado Desert Areas, with less than 5 per cent of the runoff of California, have the potential to use 18 per cent of the ultimate developed water supply of the State.

The data developed in State Water Resources Board Bulletins Nos. 1 and 2 demonstrate the basic geographical water problem of California, and also indicate the solution to that problem. From the abundant water supplies of the North Coastal Area and the Sacramento River Basin, an average of approximately 23,000,000 acre-feet of water per season will ultimately have to be developed and exported to the remaining inherently water-deficient areas of the State. These exports will be surplus waters, over and above the waters needed in the North Coastal Area and the Sacramento River Basin for ultimate local use. With the full practicable development of local water resources in all areas of the State for local use, and with the water available under California's rights in and to the waters of the Colorado River, these exports from the north will satisfy the probable ultimate requirements for water in all parts of the State.

The California Water Plan constitutes a major system of works to develop, control, and conserve the State's water resources for use in all areas of the State. It will involve exportation of conserved waters, surplus to local needs, from the North Coastal Area and the Sacramento River Basin, and the transportation of these waters to areas of deficiency elsewhere in the State, in amounts sufficient to meet the forecast ultimate requirements. The operation of these export-import facilities, collectively termed the "California Aqueduct System" is outlined in Bulletin No. 3, and their achievements and costs estimated.

The California Water Plan, comprising both the local development works and the California Aqueduct System, gives consideration to water conservation, control, protection, and use for agricultural, domestic, and industrial purposes, hydroelectric power development, flood and salinity control, water quality control, navigation, and fish, wildlife, and recreation. It contemplates the conjunctive operation of surface and ground water reservoirs, which operation will be essential to regulation of the large amounts of water ultimately to be involved.

The California Water Plan is conceived as a flexible pattern into which future definite projects may be integrated in an orderly fashion, with due consideration to varying interests. As additional data and experience are gained, as technology advances, and as future conditions change in manners that cannot be foreseen today, the plan will be substantially altered and improved.

Under The California Water Plan, local water resources will ultimately be developed to the maximum practicable extent. It follows that imports and exports of water will be limited to those amounts needed to supplement the locally developed supplies in areas of deficiency.

Under The California Water Plan, water would not be taken from those who need it; rather, it would transfer to areas of inherent water deficiency only excess or surplus water from areas of abundance. The plan is neither an inflexible regulation nor a construction proposal as it is presented herein. It does not purport to include all possible water developments in the Basin. The omission of any project from description in this bulletin does not preclude its future development into the plan.

The California Water Plan is designed to include or supplement, rather than to supersede, existing water resource development works. It will also incorporate certain of the planned works now proposed or authorized by public and private agencies and individuals. Eventually, the plan will involve construction of new works on nearly every stream in the State, and the continued use of water from the Colorado River. Furthermore, as has been stated, intelligent and planned use will be made of natural ground water reservoirs.

PLANS FOR LOCAL WATER RESOURCE DEVELOPMENT

In this section plans for local water development in the Upper Klamath River Basin, Shasta Valley, Scott Valley, and the remaining areas of the lower basin are presented. In general, the planning objective has been the development of projects that could be constructed under present economic conditions for the service of relatively large blocks of land. The projects proposed are primarily for irrigation water service, but also include multipurpose features for flood control, hydroelectric power generation, and recreation, where practicable. They would require large capital expenditures and would probably be financed, constructed, and operated by public districts. It is realized that in conjunction with these projects, numerous small water storage developments would be constructed by individuals or groups of individuals to supplement the larger developments. The results of the local water development studies made during the Klamath River Basin Investigation were incorporated into The California Water Plan.

Preliminary design of features of proposed plans for development of the water resources of the Klamath River Basin was accomplished to the extent necessary to prepare estimates of overall project costs. However, prior to preparing definite construction plans for a specific project, more detailed investigations leading to determinations of the economic justification and financial feasibility of the project should be conducted. Subsequently, still more detailed exploratory, mapping, and design studies should be made in connection with the preparation of final construction plans and specifications. It may be that final plans will differ substantially from the works described in this bulletin. However, the estimated costs presented herein are valuable for comparing the desirability of various proposed projects, indicating the approximate cost of developed water supplies, and for the initial selection of projects for additional study. No attempt was made in these preliminary studies to allocate costs of the various multipurpose features; nor was consideration given to non-reimbursable funds for items such as flood control or recreation. Therefore, costs of projects presented herein should not be construed to represent the sale prices of irrigation water.

In connection with the discussion of surface and ground water development works the following terms are used:

Safe Yield—The maximum sustained rate of draft from a reservoir that could be maintained through a critically deficient water supply period to meet a given demand for water. For purposes of this bulletin, safe yield was determined on the basis of the critical period that occurred in the Klamath River Basin from 1928-29 through 1934-35.

Irrigation Yield—The maximum sustained rate of draft from a reservoir that could be maintained through a critically deficient water supply period to meet a given irrigation demand for water, with certain specified deficiencies.

New Water—The seasonal yield of water, not otherwise available, resulting from a proposed water supply development and method of operation thereof. This includes all conserved water, whether available on a safe yield, irrigation yield, or other basis.

Dependable Power Capacity—The power plant's load-carrying ability for the time interval and period specified when related to the characteristics of the load to be supplied. In this bulletin the load requirement was assumed to have the characteristics of 3,800 kilowatt-hours per kilowatt of annual demand, that is, an annual capacity factor of approximately 43 per cent.

Installed Power Capacity—The kilowatt name plate rating of the hydroelectric generating equipment. In this bulletin the installed power capacity was determined as a result of a comparison of annual costs with revenues for several plant sizes.

Firm Annual Energy Output—The energy in kilowatt-hours that would have an assured availability to the customer to meet his load requirements. For purposes of this bulletin, it was determined to be the annual energy produced by discharge of the safe yield through the hydroelectric generating equipment.

Average Annual Energy Output—The average annual generated electric energy in kilowatt-hours that would be usable under the assumed system load for the period 1921 through 1952. For purposes of this bulletin, all of the energy output was assumed to be usable.

Operation studies of proposed reservoirs were conducted on a monthly basis for the period from 1920-21 through 1951-52. Methods used for estimating runoff were discussed in Chapter II. Operation studies of developments in the Upper Klamath River Basin were based on future impaired flows, while those in the remainder of the Basin were based on present impaired flows. Yields were generally determined on the assumption that the projects would be operated on a safe yield basis without deficiency, except that in some cases deficiencies up to 35 per cent were allowed in one year of the study.

Operation study criteria included monthly demands for irrigation water as shown in Chapter III, releases for stream flow maintenance for fisheries as recommended by the California Department of Fish and Game, and estimated evaporation based on data collected by the United States Bureau of Reclamation and the Department of Water Resources. No provisions for flood control storage allocations, except for Boundary and Callahan Reservoirs, were made in these studies. Where information was available, and where downstream water rights were significant in amount, operation studies included releases to satisfy present rights.

The geologic investigation of dam sites in the Klamath River Basin, abstract reports of which are contained herein, included review of available geologic literature and field reconnaissance of each site. Statements and conclusions regarding subsurface conditions were necessarily based on surface evidence. Extensive subsurface exploration will be required before the actual final design of any project is commenced. The geologic summaries are preliminary, and are intended only to indicate the nature and severity of geologic problems which may be encountered during construction of a dam at a given site.

Capital costs of dams, reservoirs, diversion works, conduits, pumping plants, power plants, and appurtenances included in the proposed works, were estimated from preliminary designs and based largely on data

from surveys made during the investigation. Approximate construction quantities were estimated from these preliminary designs. Unit prices of construction items were determined from recent bid data on projects similar to those planned, or from manufacturers' cost lists, and are considered representative of prices prevailing in the spring of 1956. The estimates of capital cost include costs of rights of way and interest at 3.5 per cent per annum during one-half of the assumed construction period, 10 per cent of construction costs for engineering, and 15 per cent of construction costs for contingencies. Estimates of annual costs include interest on the capital investment at 3.5 per cent, amortization over a 50-year period on a 3.5 per cent sinking fund basis, and outlay for replacement, operation, and maintenance.

Estimates of annual revenue derived from proposed hydroelectric power plants were based on a value of $22.00 per kilowatt of dependable power capacity, plus 2.8 mills per kilowatt hour of average annual energy output. Estimates of annual cost of electric energy for pumping in Scott and Shasta Valleys were based on the California-Oregon Power Company Agricultural Power Service Schedule No. 20, dated 1954. The estimated cost of electric energy for pumping water from the Klamath River into Shasta Valley was based on the use of off-peak energy, using rates of $0.003 per kilowatt-hour, and a service charge of $0.35 per kilowatt per month for the highest kilowatt demand in a 12-month period.

Developments Within the Upper Klamath River Basin

The Upper Klamath River Basin, as discussed herein, includes all lands tributary to the Klamath River above the California-Oregon state line as well as the closed drainage basins of Lost River and Butte Valley in both states. The Upper Basin embraces an area of about 7,400 square miles in California and Oregon and contains several watersheds. It is considered here as a unit for planning purposes, because of the required integrated use of the water resources.

It was shown in Chapter III that, under conditions of ultimate development, the seasonal water requirement of the Upper Klamath River Basin would be about 1,920,000 acre-feet, as compared to the present seasonal water requirement of about 1,340,000 acre-feet. About 242,000 acre-feet of the ultimate seasonal water requirement would occur in the water-deficient areas of Butte Valley and the Oklahoma District. The areas above Upper Klamath Lake, including Williamson River, Sprague River, and Wood River would ultimately have seasonal water requirements estimated to be about 969,000 acre-feet. The Lost River and Klamath Project areas, both in Oregon and California, would have ultimate seasonal water requirements estimated to be about 668,000 acre-feet.

That part of the ultimate supplemental water requirements in the Oklahoma District and Butte Valley which could not be met by development of local supplies would amount to about 160,000 acre-feet seasonally. Supplemental water supplies to meet these requirements could be developed from the Klamath River above Keno.

To determine the ultimate available water supply for the Oklahoma District and Butte Valley, a complete analysis was made of water supply and water requirements in the entire Upper Klamath River Basin. A proposed plan of development was then formulated to meet the ultimate water requirements in both Oregon and California. Water supply development in the Upper Klamath River Basin, as shown on Plate 17, would comprise three storage reservoirs, Boundary Reservoir on Lost River, and Beatty and Chiloquin Narrows Reservoirs on Sprague River. Beatty and Chiloquin Narrows Reservoirs would be in Oregon, but would develop water to be used in both Oregon and California. The plan for importation of water into Butte Valley, shown on Plate 17, represents the present proposal of the United States Bureau of Reclamation for the Butte Division of the Klamath Project.

Boundary Reservoir. Boundary Dam, proposed by the United States Bureau of Reclamation as a water conservation feature of the Klamath Project, would be located on Lost River where it crosses the California-Oregon state line, about nine miles downstream from the existing Clear Lake Dam. Although the dam would be located on the state line, the reservoir would lie entirely within California. An earthfill structure 125 feet in height would create a reservoir with a storage capacity of 100,000 acre-feet. The estimated average seasonal inflow into Boundary Reservoir would be about 110,000 acre-feet.

Boundary Reservoir, in conjunction with some flood control storage space in Clear Lake Reservoir, would provide a seasonal irrigation yield of about 41,000 acre-feet, as compared with a present yield of about 22,000 acre-feet from the existing Clear Lake Reservoir. Much of the increased yield would accrue from conserving water now evaporated from Clear Lake.

The Bureau of Reclamation plans envision that portions of the existing Clear Lake reservoir area would be reclaimed for irrigated agriculture, while other areas would be utilized as a controlled marsh for the benefit of migratory waterfowl. Flood protection to lands bordering Lost River and Tule Lake would be provided by 35,000 acre-feet of flood control storage space in Boundary Reservoir, as well as additional storage for excess waters in the Clear Lake marshes, proposed to be reclaimed for wildfowl purposes.

The capital cost of Boundary Dam and Reservoir has been estimated to be about $4,000,000, with a

corresponding annual cost of about $195,000 computed at 3.5 per cent interest. The cost of development of 41,000 acre-feet of safe seasonal yield would be about $4.80 per acre-foot. However, portions of the cost would be allocated to flood control and wildlife management. If the project were built as a part of the reclamation project, the irrigation costs would be repaid without interest.

Beatty Reservoir. Beatty Dam would be located on Sprague River in Oregon about two miles east of the town of Beatty. A dam at this site has been proposed by the United States Bureau of Indian Affairs as a means of developing a water supply for irrigable lands in the Klamath Indian Reservation. An earthfill structure, 55 feet in height, would create a reservoir with a gross storage capacity of about 150,000 acre-feet. The average seasonal inflow to the reservoir was estimated to be about 130,000 acre-feet. An irrigation yield of 110,000 acre-feet per season could be obtained from this reservoir to meet demands in Sprague River Valley. However, with this irrigation demand, deficiencies would occur in each of the four seasons, 1930-31 through 1933-34.

The capital cost of Beatty Dam was estimated to be $4,700,000 and the corresponding annual cost would be about $233,000 computed at 3.5 per cent interest. The cost of development of 110,000 acre-feet per season would be about $2.10 per acre-foot.

Chiloquin Narrows Reservoir. Additional water conservation storage above the main distribution point of the Klamath Project at Link River will be necessary, if the ultimate water requirements of the Upper Klamath River Basin are to be fully met. It was assumed that Upper Klamath Lake will continue to be operated with its present active storage capacity of 483,000 acre-feet, although nearly twice this storage capacity would be required to effect maximum regulation of the available water supply under ultimate conditions. In lieu of increasing storage in Upper Klamath Lake, the construction of Chiloquin Narrows Reservoir on Sprague River above its confluence with the Williamson River was considered. This reservoir, with a gross storage capacity of 440,000 acre-feet, would be formed by a 135-foot earthfill dam. Under ultimate conditions of development, the average seasonal inflow into the reservoir would be about 280,000 acre-feet. The average seasonal release from Chiloquin Narrows Reservoir into Upper Klamath Lake for use on lands served from the lake would be about 190,000 acre-feet.

The capital cost of Chiloquin Narrows Dam and Reservoir would be about $7,100,000 and the corresponding annual cost would be about $361,000 computed at 3.5 per cent interest. The cost of development of 190,000 acre-feet per season would be about $2 per acre-foot.

With the three storage facilities described, in addition to existing storage, supplies would be developed sufficient to meet the ultimate irrigation, municipal, and miscellaneous demands in the Klamath Project and irrigable areas in the Oklahoma District and Butte Valley, and to maintain a constant flow of about 275 second-feet in Klamath River at Keno for generation of hydroelectric power. Satisfaction of these demands, as previously discussed in Chapter III under the heading, "Future Change in Flow of the Klamath River," would require an average seasonal irrigation diversion from Upper Klamath Lake of about 580,000 acre-feet, and an average seasonal power release of about 200,000 acre-feet. The irrigation diversion would include water to serve the present Klamath Project demands, planned project extensions, and an allowance of 200,000 acre-feet for export to Butte Valley and the Oklahoma District.

Klamath Project Extensions. The United States Bureau of Reclamation has studied various methods of developing additional water supplies for Klamath Project lands, as well as for adjacent areas. The recommendation has been made that the existing system of pumping plants and canals on the Klamath Project be enlarged and extended to serve irrigation water to an additional 14,000 acres of land scattered along the fringes of the present project area. This work, referred to as Klamath Project Extensions, includes enlargement of the C-4 Canal, D Canal, F Canal, and G Canal, enlargement of Miller Hill pumping plant, construction of Stukel and Poe Valley pumping plants, and improvement of drainage facilities. The seasonal water requirement of 41,000 acre-feet would be made available by making greater use of the Lost River diversion channel to convey water from Klamath River to Lost River, and by making greater use of the flows of Lost River. These works are discussed in the report of the United States Bureau of Reclamation published in 1955 entitled "Klamath Project Extensions, A Report on the Feasibility of Irrigation Water Service."

Butte Valley-Oklahoma District Development. Under a cooperative contract with the Butte Valley Water Development Association, a plan to serve the better quality valley floor lands in Butte Valley and the Oklahoma District was developed by the Bureau of Reclamation. During the current investigation these plans were reviewed and found to be feasible of accomplishment. The Bureau of Reclamation proposals for water service to Butte Valley, known as the Butte Division of the Klamath Project, include a physical plan for water service, designs and estimates of costs of the required structures, and an evaluation of economic justification and financial feasibility.

The Butte Division of the Klamath Project would provide an average seasonal diversion of about 100,000 acre-feet from the Klamath River at Klamath Straits.

This water supply would be available from water presently conserved in Upper Klamath Lake under water rights held by the United States, and under terms of the contract between the Bureau of Reclamation and the California-Oregon Power Company for the operation of Upper Klamath Lake. As shown on Plate 17, the water diverted from Klamath River would be conveyed southward by gravity through the Klamath-Dorris Canal to the vicinity of Indian Tom Lake. About 33,000 acre-feet per season would be diverted from the canal eastward into the Oklahoma District by means of the Oklahoma Canal, and the remainder would be pumped into Butte Valley.

The Oklahoma Canal would be a gravity conduit, extending about five miles south of Sheepy Lake along the drainage channel of Willow Creek. A number of pumping plants would provide water service to lands adjacent to the canal, and would pump into canals serving the higher lands.

Irrigation deliveries in the Oklahoma District would be from water imported through the Oklahoma Canal, plus return flows which would be allowed to drain into this canal. At the end of the irrigation season the import canal system would be utilized as a drainage system by pumping back into the Klamath-Dorris Canal from the Oklahoma Canal. A pumping plant at the intake of the Klamath-Dorris Canal would discharge drain water back into the Klamath River from both the Oklahoma and Butte Valley systems.

The Dorris pumping plant, south of Indian Tom Lake, would have a capacity of 250 second-feet and would divert about 67,000 acre-feet per season from the Klamath-Dorris Canal into Butte Valley. The water would be lifted about 154 feet and conveyed through a short tunnel to the Dorris-Meiss Canal for gravity conveyance southwestward across Butte Valley to Meiss Lake for storage and regulation. New dikes would be constructed to contain Meiss Lake in two adjacent compartments, with 21,000 acre-feet of storage space in the northerly section and 7,500 acre-feet of storage space in the southerly section. A low pump lift would be required to transfer imported water from the Dorris-Meiss Canal into the lake. Distribution of water in Butte Valley would be accomplished by additional gravity canals and a number of small pumping plants.

A possible method of operating the Butte Division would be to fill Meiss Lake to capacity prior to the irrigation season, both by local runoff and water diverted from the Klamath River. During the first part of the irrigation season, water pumped directly from the Klamath River would be served to irrigated lands. When the irrigation demand exceeded the capacity of the Dorris pumping plant, stored water in Meiss Lake would be used to supplement the surface diversion, the water in the 7,500 acre-foot compartment being first utilized.

During the first part of the irrigation season the return flows from irrigated lands would be allowed to enter the main canals and to mix with imported water. As the salt concentration of the return water became greater during the latter part of the irrigation season, return flows would be collected in drains and pumped into the previously emptied smaller compartment of Meiss Lake. This water would be mixed with imported water throughout the season within limitations permitted by water quality considerations. At the end of the irrigation season all waters of undesirable quality impounded in Meiss Lake would be drained from Butte Valley through the same canal system used to import the water supply.

The project would serve water to about 45,000 acres in Butte Valley and to about 13,000 acres in the Oklahoma District, including about 8,000 acres of government-owned lands in Butte Valley and 4,500 acres in the Oklahoma District. The project area would also include the Butte Valley Irrigation District lands and lands now privately irrigated by ground water pumping. Such lands would be provided with drainage facilities and supplemental water supplies where needed.

Engineering and economic studies of the Bureau of Reclamation indicate that by making full use of all lands as proposed for project planning purposes, the project would be economically justified and financially feasible. Total project costs have been estimated to be about $19,000,000, of which about 75 per cent would be for Butte Valley works and about 25 per cent would be for Oklahoma District works. The overall benefit-cost ratio has been estimated to be favorable. The cost of irrigation water service has not yet been determined.

Several alternatives to the Butte Division project have been considered. One of these would be essentially as heretofore described, but would provide drainage from Meiss Lake by a canal and a low pump lift to convey the water through the Sam's Neck area, west of Dorris. The cost of this project would be comparable to the one discussed, and it would have a further advantage of providing low-cost drainage as an initial step in development. No final recommendation has been made for the Butte Division by the Bureau of Reclamation.

Developments Within Shasta Valley

It has been previously shown that there are sufficient water supplies in the Shasta Valley Hydrographic Unit to meet present water requirements, if those supplies are adequately regulated. Under ultimate development, however, the supplemental water requirement will be about 270,000 acre-feet seasonally. Even at the present time, because of insufficient regulation of surface water there is a problem of irrigation deficiencies in below-normal water supply seasons.

These deficiencies occur on lands irrigated from small streams tributary to the valley, and have limited the development of new irrigable lands.

Several proposed systems of works for present and future development of the surface water supply of Shasta Valley are outlined in this section. These plans of local development include the Montague Project, Grenada Ranch Project, and Table Rock Reservoir. However, complete satisfaction of the ultimate supplemental water requirement will require the importation of water from outside the valley. Plans for the proposed Shasta Valley Import Project include works for regulating and conveying a water supply from the Klamath River to Shasta Valley. The foregoing projects are not alternatives in the sense of providing service to identical areas. However, they are interdependent to the extent that construction of either the Grenada Ranch or Table Rock projects will affect the anticipated yield of the Montague project. The locations of these projects are shown on Plate 18, "Existing and Possible Future Developments, Shasta Valley."

Subsequent to completion of planning studies for this bulletin, additional studies of plans for water development in Shasta Valley were made in 1958 and 1959. These new studies included more detailed investigation of the Montague and Grenada Ranch Projects, as well as investigation of the Gregory Mountain Project located on the Shasta River near Montague. Further study was also made of the Shasta Valley Import Project. The economic justification of these projects was evaluated to determine whether one or more of the water developments should be considered for construction in the near future. As a result of the more detailed geologic and economic studies it was found that the Montague Project would not be feasible because of excessive costs that would be required to overcome poor foundation conditions. The Gregory Mountain Project featuring a dam on the Shasta River about four miles upstream from the Montague dam site has been proposed as an alternative to the Montague Project. A report on these studies is scheduled for publication in 1960.

Montague Project. The Montague Project was proposed to serve irrigable lands in the vicinity of the town of Montague. It would be susceptible of staged development and, with completion of the final stage, would regulate the flow of the Shasta River as well as return flows of water imported from the Klamath River. Operation of the project would provide new water for irrigation and other purposes, and for stream flow maintenance for the improvement of downstream conditions. However, as stated above, studies in 1958 and 1959 showed this project to be less desirable than the Gregory Mountain Project because poor foundation conditions at the Montague dam site would increase design requirements and costs.

The Montague Project includes Montague Dam and Reservoir on the Shasta River; the North Pumping Plant, serving water for the irrigable area north of the reservoir; and the South Pumping Plant serving water for the irrigable area south of the reservoir. Locations of features of the project are shown on Plate 18, and the principal features of the dam are delineated on Plate 21, "Montague Dam on Shasta River and Table Rock Dam on Little Shasta River."

Montague Reservoir would provide an estimated safe yield of 84,000 acre-feet of new water seasonally, of which 62,000 acre-feet would be pumped for irrigation, and 22,000 acre-feet would be released for stream flow maintenance. In addition, an average of 12,000 acre-feet of unregulated water would be made available seasonally from the reservoir to satisfy existing rights.

It was assumed that the service area of the project would include lands in northern Shasta Valley presently without a water supply, lands now served by the Shasta Water Users Association, and a portion of the lands in the Montague Water Conservation District, totalling about 20,000 acres between elevations of 2,500 and 2,700 feet. Lands in the proposed service area presently supplied from Dwinnell Reservoir would, after project completion, receive water from Montague Reservoir, releasing the water supply from Dwinnell Reservoir for use on lands closer to the reservoir.

The service area of the Montague Project was divided into South and North Units, served by similarly designated pumping plants and main canals. The South Service Area has a net irrigable area of 6,900 acres, and would require a water supply of approximately 25,000 acre-feet seasonally. The North Service Area contains about 13,600 irrigable acres, and would require approximately 49,000 acre-feet each season.

A seasonal summary of a monthly yield study of the project for the period from 1920-21 through 1951-52, utilizing estimates of present impaired flow of the Shasta River, is presented in Appendix E. Presented in Table 48 is the estimated monthly distribution of water from Montague Reservoir for irrigation and for fishery maintenance.

Preliminary geologic reconnaissance indicated that the Montague site would be suitable for an earthfill dam of the proposed height of 108 feet. The abutment slopes are relatively gentle, and are largely soil-covered in their lower parts. Serpentine rock, quite hard where fresh and unweathered, outcrops over much of the upper portion of the abutments, above a height of 80 feet above streambed on the right abutment and above 150 feet on the left abutment. Outcrops of metaigneous rock, a hard, grey, medium- to fine-grained material, broken by many random joints and by shears of minor extent, exist in the lower abutment areas. The geologic investigation of the Montague site made by drilling in 1958 showed foundation condi-

tions to be extremely poor. The channel sections contain wide fault zones composed of gouge and breccia which have no apparent shear strength. The abutments contain weak, brecciated (fragmental) rock. These conditions would create many difficult design and construction problems. However, if necessary, a safe earth or rock fill dam could be constructed at this site, but it would be very costly.

Impervious construction materials are plentiful in the flats around Ager Road Bridge, within one mile of the dam site. Pervious material is available in limited quantities in the Shasta River channel, and in dredger tailings along Yreka Creek which enters the Shasta River about one mile downstream from the dam site. Pervious material required in addition to available stream gravels could be obtained from stripping spoils and rock quarried locally. Aggregates are also available in the immediate vicinity but they would require washing and sorting.

The proposed dam would be 93 feet in height from streambed to spillway lip, with a crest length of 1,475 feet. The reservoir would have a normal pool storage capacity of 87,000 acre-feet. The spillway would be designed for a discharge of 7,200 second-feet. It would be an ungated concrete structure located on the left abutment. Protection to the toe of the dam would be provided, as well as some channel improvement from the spillway chute to Yreka Creek.

The outlet works would consist of two welded steel pipes placed under the dam, one each on the right and left sides of the channel. They would terminate in the North and South Pumping Plants, respectively, which would raise water to elevations suitable for delivery to the service areas.

Montague Reservoir would inundate an area of about 2,700 acres at normal water surface elevation. Table 49 lists the area and storage capacity for various pool elevations. Acquisitions of about 4,600 acres of land would be required in order to provide adequate perimeter area and to accord with existing land ownership boundaries. Inasmuch as the proposed reservoir would cut off approaches to Montague from the west and south, replacement of the existing highways and railroads would be required. Power and telephone lines along the present Yreka-Montague highway would be rerouted.

TABLE 48

ESTIMATED MONTHLY DISTRIBUTION OF DEMAND FOR WATER FROM MONTAGUE RESERVOIR

(In acre-feet)

Month	South Service Area	North Service Area	Stream flow maintenance release	Totals
April	2,500	5,100	1,200	8,800
May	4,600	9,000	1,200	14,800
June	4,200	8,100	1,200	13,500
July	5,400	10,400	1,200	17,000
August	5,000	9,800	1,200	16,000
September	3,300	6,600	1,200	11,100
October	0	0	2,500	2,500
November	0	0	2,500	2,500
December	0	0	2,500	2,500
January	0	0	2,500	2,500
February	0	0	2,300	2,300
March	0	0	2,500	2,500
TOTALS	25,000	49,000	22,000	*96,000

* Includes an average of 12,000 acre-feet of unregulated water per season to be made available to replace existing water rights.

TABLE 49

AREAS AND CAPACITIES OF MONTAGUE RESERVOIR

Depth of water at dam, in feet	Water surface elevation, USGS datum in feet	Water surface area, in acres	Storage capacity, in acre-feet
0	2,407	0	0
13	2,420	50	300
33	2,440	480	5,600
53	2,460	950	19,700
73	2,480	1,670	44,500
93	2,500	2,670	87,000
103	2,510	3,960	120,200

Pertinent data with respect to general features of the Montague Project, as developed for cost estimating purposes, are presented in Table 50. Detailed estimates of the cost of the dam and pumping facilities are presented in Appendix F.

The capital cost of the Montague Project was estimated to be about $7,990,000, and the corresponding annual cost for the physical features, operation, and maintenance was estimated to be about $580,000. The costs of main and distribution canals are not included in these figures. An additional annual cost, not included in the above estimate, would be the cost of pumping 74,000 acre-feet of water seasonally from the reservoir for delivery to adjacent service areas. Using the California-Oregon Power Company Agricultural Power Service Schedule No. 20, 1954, this has been estimated to be about $135,000 per year. The unit cost of development of 84,000 acre-feet per season would be about $8.50 per acre-foot. This does not represent the price of irrigation water at the head of the distribution system since no consideration was given to portions of the cost to be borne by recreation and stream flow maintenance purposes or to possible nonreimbursable grants to the project.

Grenada Ranch Project. The Grenada Ranch Project would include Grenada Ranch Dam and Reservoir on the Shasta River, approximately 2.5 miles southeast of Grenada; a pumping and filtration plant near the base of the dam; and a pipe line approximately 11 miles in length to the City of Yreka. These facilities would provide approximately 3,000 acre-feet of water seasonally, equivalent to 2.7 million gallons per day, for municipal use, and approximately 17,000 acre-feet of water seasonally for irrigation use. Municipal water requirements of the cities of Grenada

TABLE 50

GENERAL FEATURES OF MONTAGUE PROJECT

Dam	
Type	earthfill
Crest elevation, in feet	2,515
Crest length, in feet	1,475
Crest width, in feet	30
Height, spillway lip above stream bed, in feet	93
Elevation of stream bed, in feet	2,407
Side slopes, upstream	3:1
downstream	2.5:1
Freeboard above spillway lip, in feet	15
Volume of fill, in cubic yards	1,435,000
Reservoir	
Surface area at spillway lip, in acres	2,700
Storage capacity at spillway lip, in acre-feet	87,000
Drainage area, in square miles	796
Estimated average seasonal runoff, in acre-feet	137,500
Estimated safe seasonal yield, in acre-feet	84,000
Type of spillway—uncontrolled lined chute over the left abutment	
Spillway discharge capacity, in second-feet	7,200
Type of outlet—two 72-inch welded steel pipes under the dam	
South Pumping Plant	
Pumps—five 10,000 gpm centrifugal units	
Motors—two 400 horsepower and three 800 horsepower	
Estimated maximum pumping head, in feet	221
Installed pumping discharge capacity, in second-feet	90
North Pumping Plant	
Pumps—two 17,500 gpm and three 20,600 gpm centrifugal units	
Motors—two 800 horsepower and three 1,500 horsepower	
Estimated maximum pumping head, in feet	224
Installed pumping discharge capacity, in second-feet	169

and Montague could also be met by the water supply made available. However, estimates of the cost of these possible additional municipal services were not made.

The proposed works necessary to serve a municipal water supply to the City of Yreka were included in the project in anticipation of a future need for water over and above supplies presently being developed. The Grenada Ranch Project would be susceptible of staged development. The first stage would consist of those works necessary to provide water for irrigation service only, while the second stage would consist of the additional facilities required for municipal service.

Location of the features of the Grenada Ranch Project are shown on Plate 18, "Existing and Possible Future Developments, Shasta Valley," and its principal features are delineated on Plate 22, "Grenada Ranch Dam on Shasta River."

The dam site is located in a moderately steep-sided gorge cut by the Shasta River into the volcanic rocks forming the irregular knobby floor of the broad Shasta Valley. Geologic reconnaissance during the Klamath River Basin Investigation resulted in the conclusion that the Grenada Ranch dam site would be suitable for an earthfill or rockfill dam of the proposed height of 62 feet. The design and cost estimates presented herein, based on the geologic reconnaissance, include stripping of 6 feet of loose-jointed blocks and rubble from the abutments, and an additional 14 feet of jointed volcanic rock from under the impervious section.

Material suitable for impervious fill is available in the reservoir area and just downstream from the dam site. Ample quantities of jointed rock are available at and near the site for all pervious fill required.

Subsequent and more extensive geologic investigations, conducted in 1958 during the Shasta Valley Investigation, showed that the valley section at the dam site is filled with sand, gravel, and boulders to depths greater than 100 feet. A dam designed with knowledge of the later information may require a cut-off section approximately 50 feet deep into the channel, as well as heavy grouting along the entire length of the axis. Even with the grout curtain extending well beyond the ends of the structure, leakage through the porous, jointed volcanic rock may occur. Also, with more detailed geologic knowledge, an alternative spillway location to the left of the dam site may be incorporated in the dam in place of the spillway as designed for studies contained herein.

The selection of the height of the proposed Grenada Ranch Dam was influenced by the location of Big Springs, the available water supply in the Shasta River, the possible need for saddle dams around the rim of the reservoir, and the location of a suitable spillway site. It was concluded that water surface in the proposed reservoir should be held lower than Big Springs since flooding of the springs might adversely affect their rate of flow. In consideration of the foregoing factors, it was determined that the maximum feasible storage capacity of the reservoir would be about 22,800 acre-feet. Reservoir storage capacities for various pool elevations are given in Table 51.

Operation studies of Grenada Ranch Reservoir indicated that there are unregulated flows in the Shasta River of sufficient magnitude to yield 20,000 acre-feet of new water seasonally over and above existing rights. Rights to the entire flow of the Shasta River during the irrigation season extending from April 1st to October 1st have been established by adjudication procedures. Consequently stream flow during that period would not be available for storage in Grenada Ranch Reservoir.

In addition to the adjudicated rights to the flow of the Shasta River during the irrigation season, a right to winter floodwater from Parks Creek, in the amount of 15,000 acre-feet per season, is held by the Montague Water Conservation District. These latter waters are stored in Dwinnell Reservoir, located upstream from the proposed Grenada Ranch Reservoir.

The existing Grenada Irrigation District pumping plant would be inundated by the reservoir. Provision would be made for replacement of this pumping plant, and for the release of up to 120 second-feet during the irrigation season to satisfy prior downstream water rights.

Montague Dam site on Shasta River looking south from air over right abutment to left abutment

Department of Water Resources photograph

Kidder Creek in Scott Valley, looking west from air over Fort Jones. Scars of the December 1955 flood border the stream.

Siskiyou Airways, Montague, photograph

TABLE 51

AREAS AND CAPACITIES OF GRENADA RANCH RESERVOIR

Depth of water at dam, in feet	Water surface elevation, USGS datum in feet	Water surface area, in acres	Storage capacity, in acre-feet
0	2,528	0	0
2	2,530	4	4
12	2,540	175	900
22	2,550	339	3,470
32	2,560	461	7,470
42	2,570	745	13,500
52	2,580	1,115	22,800
62	2,590	2,069	38,720

Grenada Ranch Dam would be an earthfill structure 62 feet in height with a crest length of 550 feet. Stream bed elevation at the dam site is 2,528 feet. The dam would have an upstream impervious section of compacted earth and a downstream pervious section of gravel and rock. A small auxiliary dam would be required south of the left abutment. An overpour spillway, with a design discharge capacity of 12,000 second-feet, and maximum depth of water of 6 feet above the spillway lip, would be provided. Freeboard on the dam, above the maximum water surface elevation in the reservoir, would be 4 feet.

Irrigation water supplies would be released through a 36-inch diameter welded steel pipe located beneath the dam. Outlet works for municipal water supplies would consist of a 24-inch diameter steel pipe, located beneath the right abutment of the dam. The municipal outlet would terminate in a combination pumping and filtration plant structure located immediately downstream from the dam.

A maximum area of 2,600 acres including lands used for cattle ranching and for irrigated pasture and meadow hay would be inundated by the Grenada Ranch Reservoir.

From the pumping and filtration plant water would be conveyed in a 14-inch diameter steel pipe to Yreka and the conduit would be about 11 miles in length. The conduit would connect with the present municipal water supply system at the Boston Shaft. The filtration plant would have a maximum capacity of about 1,800 gallons per minute, and would be capable of delivering to Yreka about 1,500 acre-feet of water seasonally.

The capital cost of the Grenada Ranch Project was estimated to be about $2,030,000. The annual cost, for both an irrigation supply and for delivering a municipal water supply to Yreka, would be about $120,000. The unit cost of development of 20,000 acre-feet per season would be $6 per acre-foot. Prices for water would depend upon the proportion of water used for municipal and irrigation purposes. These costs do not reflect increased costs that would be required for additional design requirements and foundation treatment shown necessary by the detailed geologic investigation in 1958.

Pertinent data with respect to general features of the proposed Grenada Ranch Project are presented in Table 52. A detailed cost estimate of the project is presented in Appendix F.

TABLE 52

GENERAL FEATURES OF GRENADA RANCH DAM AND RESERVOIR

Grenada Ranch Dam	
Type	earthfill
Crest elevation, in feet	2,590
Crest length, in feet	550
Crest width, in feet	25
Height, spillway lip above stream bed, in feet	52
Stream bed elevation, in feet	2,528
Side slopes	2:1
Freeboard above spillway lip, in feet	10
Volume of fill, in cubic yards	167,500
Reservoir	
Surface area at spillway lip, in acres	1,115
Storage capacity at spillway lip, in acre-feet	22,800
Drainage area, in square miles	352
Estimated average seasonal runoff, in acre-feet	97,000
Estimated safe seasonal yield, in acre-feet	20,000
Type of spillway—ungated, unlined chute over right abutment	
Spillway discharge capacity, in second-feet	12,000
Type of outlet—one 36-inch steel pipe and one 14-inch steel pipe encased in concrete under the dam	
Yreka Pumping Plant	
Pumps—two 900 gpm centrifugal pump units	
Motors—two 150-horsepower motor units	
Estimated maximum pumping head, in feet	320
Installed pumping discharge capacity, in second-feet	4
Yreka Conduit	
Conduit—14-inch diameter steel pipe, 10.9 miles in length, with a capacity of 4 second-feet	

Table Rock Reservoir. Table Rock Reservoir would provide regulation of the erratic natural flow of Little Shasta River, and would make available a seasonal safe yield of 11,800 acre-feet of water. This yield would not be new water, since the available stream flow is not sufficient to provide a water supply in excess of the average amount presently diverted and used. Construction of the reservoir would, however, provide the basis for a greater economic use of both water and land.

Table Rock Dam and Reservoir would be located on the Little Shasta River about 9 miles east of the town of Montague. The location of the reservoir is shown on Plate 18, and the general features of the dam are delineated on Plate 21. The stream bed elevation at the dam site is 2,810 feet. The construction of a saddle dam about 0.8 mile southeast of the left abutment would be required. Reservoir storage capacities for various pool elevations are presented in Table 53.

A preliminary geologic reconnaissance, and consideration of available materials, indicate that this dam site is best suited for an earthfill type structure of moderate height. The abutments and adjacent slopes

TABLE 53

AREAS AND CAPACITIES OF TABLE ROCK RESERVOIR

Depth of water at dam, in feet	Water surface elevation, USGS datum in feet	Water surface area, in acres	Storage capacity, in acre-feet
0	2,810	0	0
30	2,840	44	660
60	2,870	205	4,400
90	2,900	408	13,600
120	2,930	552	28,000

are gentle and undulating. Soil covers most of the area, with a slightly porphyritic, vesicular, dark-colored basaltic rock of Tertiary age outcropping at various points such as road cuts and stream banks. Surficially, the rock appears to be badly fractured and weathered. The fracturing, due primarily to jointing, may continue to a considerable depth beneath the ground. In this type of material, leakage from a reservoir may be a serious problem.

The estimated depth to sound foundation rock is 5 feet on the left abutment and 10 feet on the right abutment. Geological exploration of the channel section would be necessary to determine accurately the depth and type of channel fill, and it is estimated that there may be as much as 50 feet of soil, sand, gravel, and rock.

Foundation conditions at the saddle dam site are similar in most respects to those of the main dam site, although only a shallow soil blanket appears to cover the bedrock across the bottom of this site. Materials suitable for construction of the dam are available at or near the site. Gravels suitable for drain rock or aggregate would have to be imported from outside the reservoir area.

The average seasonal runoff from the 18 square miles of drainage area above the proposed Table Rock Dam is estimated to be 21,400 acre-feet. Results of monthly yield studies made for reservoir storage capacities between 8,000 to 28,000 acre-feet, compared with preliminary estimates of the cost of the dam for each capacity, indicate that the most economical height of dam would be about 90 feet. The reservoir storage capacity at this height would be 10,000 acre-feet, and the seasonal irrigation yield, without deficiencies in any year, would be about 11,800 acre-feet. A summary of the yield study is presented in Appendix E.

The proposed Table Rock Dam would be an earthfill structure, 90 feet in height, from stream bed to crest of the dam, and the dam would have a crest length of 2,100 feet. The upstream section of the dam would consist of impervious compacted earth material, and the downstream portion would consist of pervious materials with three feet of riprap slope protection.

A chute spillway, with a design discharge capacity of 750 second-feet with a maximum depth of water of 4 feet above the spillway lip, would discharge into the stream channel about 500 feet below the toe of the dam. Outlet works would consist of two 30-inch diameter welded steel pipes, one under each abutment of the the dam. An additional 12-inch diameter outlet pipe would be placed under the right abutment at about elevation 2,865 feet to provide diversion of excess flows to existing downstream off-channel storage reservoirs.

The reservoir area contains about 100 acres of irrigated land. The remaining area is dry-farmed land and uncultivated hillsides. Improvements that would be inundated by Table Rock Reservoir include a ranch with several buildings and two residences. About 3 miles each of county road, electric power lines, and telephone lines, would require relocation.

The capital cost of Table Rock Dam and Reservoir was estimated to be about $2,690,000, and corresponding annual costs were estimated to be $130,000. The unit cost of development of 11,800 acre-feet per season would be about $11.00 per acre-foot. A detailed cost estimate is presented in Appendix F.

Pertinent data with respect to general features of Table Rock Reservoir, as designed for cost estimating purposes, are presented in Table 54.

TABLE 54

GENERAL FEATURES OF TABLE ROCK DAM AND RESERVOIR

Dam	
Type	earthfill
Crest elevation, in feet	2,900
Crest length, in feet	2,100
Crest width, in feet	30
Height, spillway lip above stream bed, in feet	80
Stream bed elevation, in feet	2,810
Side slopes, upstream	2.5:1
downstream	2:1
Freeboard above spillway lip, in feet	10
Volume of fill, in cubic yards	1,555,500
Auxiliary Dam	
Type	earthfill
Crest length, in feet	2,030
Crest width, in feet	30
Height of crest above natural ground, in feet	25
Side slopes	2.5:1
Volume of fill, in cubic yards	127,000
Reservoir	
Surface area at spillway lip, in acres	370
Storage capacity at spillway lip, in acre-feet	10,000
Drainage area, in square miles	84
Estimated average seasonal runoff, in acre-feet	21,400
Estimated safe seasonal yield, in acre-feet	11,800
Type of spillway—ungated ogee weir with lined chute through left abutment	
Spillway discharge capacity, in second-feet	750
Type of outlet—two 30-inch diameter and one 12-inch diameter steel pipes encased in concrete beneath the dam	

Shasta Valley Import Project. The Shasta Valley Import Project would comprise those features necessary for regulating and conveying a water supply from the Klamath River to Shasta Valley. It would include the construction of Iron Gate Dam and Reser-

voir on the Klamath River, Iron Gate Pumping Plant, Ager Pumping Plant, Red School Dam and Reservoir, and the Bogus Conduit extending from the Klamath River to Red School Reservoir. The locations of these features are shown on Plate 18.

The Shasta Valley Import Project is designed for a seasonal pump diversion of 122,000 acre-feet from the Klamath River. The Ager subunit, tributary to the Klamath River, would utilize 20,000 acre-feet per season of the total amount of water pumped, to provide for the ultimate water requirement of that subunit. The remaining 102,000 acre-feet per season would be conveyed into Shasta Valley to augment local supplies to provide water to most of the better quality irrigable lands. To completely meet the ultimate water requirements of the Shasta Valley Hydrographic Unit except for the Grass Lake Subunit, it is estimated that an additional 100,000 acre-feet would have to be imported from the Klamath River. Return flows from new water imported into Shasta Valley would increase the yield of the proposed Montague Reservoir or alternative reservoirs on the Shasta River. It is estimated that the initial import would increase the yield of Montague Reservoir by about 40,000 acre-feet.

1. *Iron Gate Dam and Reservoir.* The diversion from the Klamath River would be made from Iron Gate Reservoir on the Klamath River. This reservoir would function both as a forebay to the proposed pumping plant and as an afterbay to existing and proposed hydroelectric power developments upstream. Downstream releases to the Klamath River from Iron Gate Reservoir would be maintained at constant rates for long periods of time. Changes in flow in the river would be accomplished by gradual change in the rate of release from the reservoir.

Iron Gate Dam would be located on the Klamath River about one quarter mile upstream from the mouth of Brush Creek. The stream bed elevation at the dam site is 2,168 feet. Pertinent details of the proposed dam are shown on Plate 20.

The required active storage capacity of Iron Gate Reservoir was estimated at 16,400 acre-feet. This capacity would provide storage for three days diversion requirements amounting to 2,500 acre-feet to permit off-peak pumping to the Bogus Canal; carry-over storage of 3,200 acre-feet in order to maintain minimum releases of 50 second-feet; and reregulation capacity of 10,700 acre-feet of storage, equivalent to about 2½ days of flow from ultimate upstream power developments. The minimum release of 50 second-feet for stream flow maintenance was selected for engineering planning purposes under the assumption that ultimate development of downstream dams would prevent anadromous fish from reaching this area.

Based on the relationship of annual cost of pumping to annual cost of capital investment in the dam and associated structures, it was found that the most economical size of reservoir would be that which would maintain the normal pool water surface elevation of 2,300 feet. At this elevation a reservoir with a total storage capacity of 35,400 acre-feet would be required. Studies indicate that the annual cost of the power generating features required at Iron Gate Dam under the ultimate conditions considered herein would be greater than the average annual revenue from developed energy. Therefore, based on these preliminary findings, hydroelectric power development was not included as part of the proposed plan. More refined studies, or studies based on present flows may find a method of including power features in the plan of development.

A preliminary geologic reconnaissance at the Iron Gate dam site indicated that foundation conditions were suitable for a concrete gravity dam of the size under consideration. Extensive lava flows cover this area. The rock at the site is an aphanitic green-to-black basalt. Blocky jointing is prominent at the surface, although it would probably be of little concern at depth, and little shearing was noted. The rock is very hard where freshly exposed. Weathering, even on long exposed surfaces, is only moderate. Stripping would average about 15 feet on both abutments and in the channel. Concrete aggregates could be obtained from the local rock crushed at the site and sand could be hauled from the vicinity of Hornbrook.

Iron Gate Dam, as proposed, would be a concrete gravity structure with a central gated spillway section. The dam would be 137 feet in height from stream bed to crest, and the crest length of dam would be 450 feet. The gated overpour type spillway located over the river channel would have a maximum discharge capacity of 40,000 second-feet. Pertinent details of Iron Gate Dam are shown on Plate 20.

Iron Gate Reservoir, at normal pool elevation of 2,300 feet, would inundate about 740 acres of rough unimproved canyon lands. Storage capacities and water surface areas for various pool elevations in Iron Gate Reservoir are presented in Table 55. Relocation of about 7 miles of gravel road would be required.

2. *Iron Gate Pumping Plant.* The Iron Gate Pumping Plant, located at the terminus of the outlet pipe from Iron Gate Reservoir, would lift the diverted

TABLE 55

AREAS AND CAPACITIES OF IRON GATE RESERVOIR

Depth of water at dam, in feet	Water surface elevation, USGS datum in feet	Water surface area, in acres	Storage capacity, in acre-feet
0	2,168	0	0
32	2,200	62	1,000
82	2,250	338	11,000
132	2,300	638	35,400

water supply about 320 feet to the Bogus Canal. This would be the first of two lifts totaling about 500 feet from Iron Gate Reservoir at 2,300 feet to Red School Reservoir in Shasta Valley at 2,800 feet. Pumping plants would be designed to take advantage of low off-peak electric energy rates.

The Iron Gate Pumping Plant would consist of five pumps, each with a capacity of approximately 170 second-feet, and a combined capacity of 850 second-feet. The required maximum daily diversion would be pumped during a 12-hour period when the system power demand was least. The maximum static pumping lift, from the minimum water surface elevation of 2,269 feet in Iron Gate Reservoir to a water surface elevation of 2,600 feet in the Bogus Canal, would be 331 feet. The average dynamic pumping head, utilized for estimating the annual cost of pumping, would be about 320 feet. The pumping plant would have an installed capacity of 45,000 horsepower and would use an average of 57,000,000 kilowatt-hours of electrical energy each year.

3. *Bogus Conduit.* The Bogus Conduit, comprising canal, tunnel, pumping plant, and pipe line sections would originate at the end of the discharge penstock of the Iron Gate Pumping Plant, at an elevation of 2,600 feet, and would terminate in the proposed Red School Reservoir, at an elevation of 2,800 feet. The proposed Ager Pumping Plant, required to lift the diverted water into Red School Reservoir would be located in Section 33, Township 47N, Range 5W.

The first section of the conduit would be a concrete-lined canal 13,600 feet in length, with a conveyance capacity of 840 second-feet. The canal would convey water in a southerly direction to a tunnel through the ridge between Bogus Creek and Little Bogus Creek. At that point, a lined 12½ foot diameter horseshoe tunnel, 2,100 feet in length, combined with a steel pipe inverted siphon, 4,500 feet in length, would carry the water through the ridge and across Little Bogus Canyon. An additional section of lined canal between the terminus of the siphon and the Ager Pumping Plant forebay, would complete the first part of the conduit. The discharge capacity of the conduit between Iron Gate Reservoir and Ager forebay would be 840 second-feet.

From the forebay of the Ager Pumping Plant, 20,000 acre-feet of water per season would be diverted for local use in the Ager area. The remaining 102,000 acre-feet per season would be further pumped through a steel pipe line, about 2,400 feet in length, to the final section of the Bogus Canal. The pumping head on this plant would be constant. The difference in elevation between the water surface of the forebay to the pumping plant, at an elevation of 2,578 feet, and the pumping plant afterbay, at an elevation of 2,810 feet, would be 232 feet. The Ager Pumping Plant would consist of four 200 second-foot pump units with a combined installed capacity of 30,000 horsepower.

An average of 40,000,000 kilowatt-hours of electrical energy per year would be required for pumping. The final section of the Bogus Conduit between Ager Pumping Plant afterbay and Red School Reservoir, would be a lined canal about 36,000 feet in length. The capacity of this section of the conduit would be 770 second-feet.

4. *Red School Dam and Reservoir.* The proposed Red School Dam and Reservoir would be located on Willow Creek about 5 miles northeast of Siskiyou County Airport. The reservoir would have a storage capacity of 1,700 acre-feet, sufficient to provide regulatory storage for the maximum rate of water imported from the Klamath River. Water imported from the Klamath River on an off-peak pumping schedule would be released for distribution in Shasta Valley on an irrigation schedule. Natural flows of Willow Creek would be passed through the reservoir to satisfy present downstream uses. The location of the dam and reservoir is shown on Plate 18, and the general features of the dam are delineated on Plate 20.

A preliminary geologic reconnaissance of this site indicated it is an area of volcanic rocks of basaltic composition, vesicular, and slightly porphyritic. Unless unusual conditions exist which the preliminary reconaissance did not disclose, the dam site would be suitable for an earthfill dam of moderate height, but the reservoir area would probably be subject to leakage. The soils of the area are generally of good quality for impervious embankment but limited in quantity in the immediate vicinity of the dam site. Ample quantities of rock for pervious sections of the dam are available at the site.

The elevation of the stream bed at the dam site is 2,730 feet. The water surface at a normal pool elevation of 2,800 feet would be about 70 feet above stream bed. Reservoir storage capacities and water surface areas inundated for various depths of water at the dam site are given in Table 56. The drainage area above Red School Dam is about 18.1 square miles.

Red School Dam would be an earthfill structure 80 feet in height from stream bed to crest and would have a crest length of 1,950 feet. The spillway would be located on the right abutment and would have a design discharge capacity of 1,500 second-feet with a maximum depth of 5 feet above the spillway lip.

The outlet works would consist of a suitable pipe through the right abutment and appurtenant control valves. The water would be released on an irrigation schedule and delivered from the regulatory reservoir southward throughout Shasta Valley by means of canals and additional pumping plants. The design of the required distribution system was not studied in detail, nor was an estimate of cost prepared.

The reservoir area comprises approximately 66 acres of unimproved lands. No public utilities or private improvements would require relocation.

TABLE 56

AREAS AND CAPACITIES OF RED SCHOOL RESERVOIR

Depth of water at dam, in feet	Water surface elevation, USGS datum in feet	Water surface area, in acres	Storage capacity, in acre-feet
0	2,730	0	0
20	2,750	6	60
45	2,775	29	500
70	2,800	67	1,700

5. *Summary.* In summary, the Shasta Valley Import Project would include Iron Gate Dam and Reservoir on the Klamath River, the Bogus Conduit to convey approximately 122,000 acre-feet of water seasonally into Shasta Valley, two pumping plants to lift the water about 500 feet vertically, and Red School Reservoir to reregulate the imported water to provide irrigation releases. A distribution system is not included.

The capital cost of the Shasta Valley Import Project was estimated to be about $19,960,000 with the corresponding annual costs of the physical features estimated to be about $1,415,000. In addition, $522,000 would be required for the average annual cost of electric energy for pumping the total imported supply. The total annual cost would be $1,937,000. The following tabulation summarizes the estimated capital and annual costs of the features of the Shasta Valley Import Project. A detailed estimate of cost is presented in Appendix F.

Feature	*Estimated Cost* *Capital*	*Annual*
Iron Gate Dam and Reservoir	$3,982,000	$182,000
Iron Gate Pumping Plant	4,711,000	463,000
Ager Pumping Plant	3,488,000	342,000
Bogus Conduit	6,381,000	362,000
Red School Dam and Reservoir	1,402,000	66,000
Subtotal		$1,415,000
Electric Energy		522,000
TOTALS	$19,964,000	$1,937,000

The average cost of development to import 122,000 acre-feet per season into Shasta Valley would be about $16.00 per acre-foot. Detailed studies of cost allocation and possible non-reimbursable funds would be required to determine the price that would have to be paid by irrigators for this water.

Developments in Scott Valley

Deficiencies in water supply occur in portions of Scott Valley during the late summer and fall months due to the shortage of divertable unregulated stream flow. However, these deficiencies are usually small in magnitude and varying, depending upon the location of points of diversion and the availability of water supply. Therefore, present supplemental water requirements can be considered relatively minor. The ultimate supplemental water requirements for Scott Valley have been estimated to be about 60,000 acre-feet per season.

TABLE 57

GENERAL FEATURES OF SHASTA VALLEY IMPORT PROJECT

Iron Gate Dam	
Type	concrete gravity
Crest elevation, in feet	2,305
Crest length, in feet	450
Crest width, in feet	30
Height, spillway lip above stream bed, in feet	132
Stream bed elevation, in feet	2,168
Side slopes, upstream	0.05:1
downstream	0.80:1
Freeboard above spillway lip, in feet	5
Volume of concrete in cubic yards	117,000
Iron Gate Reservoir	
Surface area at spillway lip, in acres	740
Storage capacity at spillway lip, in acre-feet	35,400
Drainage area, in square miles	4,640
Estimated ultimate average seasonal inflow, in acre-feet	797,000
Type of spillway—gated overpour, three 20- by 40-foot radial gates	
Spillway discharge capacity, in second-feet	40,000
Type of outlet—10-foot diameter steel pressure pipe to Iron Gate Pumping Plant and river channel outlets as required	
Iron Gate Pumping Plant	
Pumps—five 75,000 gpm centrifugal pump units	
Motors—five 9,500 horsepower	
Estimated maximum dynamic pumping head, in feet	340
Installed pumping discharge capacity, in second-feet	840
Ager Pumping Plant	
Pumps—four 90,000 gpm centrifugal pump units	
Motors—four 7,500 horsepower	
Estimated maximum dynamic pumping head, in feet	240
Installed pumping discharge capacity, in second-feet	770
Bogus Conduit	
Canals—concrete-lined, 10.4 miles in length, bottom width of 8.0 feet, depth of water of 10.0 feet, side slopes 1:1	
Discharge capacity, in second-feet	840
Siphon—welded steel pipe, 0.85 mile in length; diameter varies from 9-11 feet	
Tunnel—12.5 foot diameter, lined horseshoe section 0.4 mile in length	
Red School Dam	
Type	earthfill
Crest elevation, in feet	2,810
Crest length, in feet	1,950
Crest width, in feet	30
Height, spillway lip above stream bed, in feet	70
Stream bed elevation, in feet	2,730
Side slopes	2.5:1
Freeboard above spillway lip, in feet	10
Volume of fill, in cubic yards	462,000
Red School Reservoir	
Surface area at spillway lip, in acres	66
Storage capacity at spillway lip, in acre-feet	1,900
Drainage area, in square miles	18
Estimated ultimate average seasonal inflow, in acre-feet	102,000
Estimated safe seasonal yield, in acre-feet	102,000
Type of spillway—ungated ogee weir with lined discharge chute across right abutment	
Spillway discharge capacity, in second-feet	1,200
Type of outlet—6-foot diameter steel pipe encased in concrete under dam	

Various plans of development, designed to regulate natural water supplies to develop new water to serve additional lands, were considered. A number of reservoirs on streams tributary to the Scott River were studied. In general, development of water by such means would be expensive because of the lack of a good reservoir site on streams to the west of Scott Valley. Very high dams would be needed to provide the required storage. However, five of these plans are presented in this section for comparative purposes. A plan to meet the water requirements of most of the valley floor of Scott Valley, and the surrounding foothill area, by development of ground water storage was also investigated. Results of these analyses indicate that supplemental water supplies could be provided by either ground water or surface water developments. In the final analysis, the best and most economical over-all plan of development to serve all of the irrigable lands in Scott Valley would be a combination of both ground water and surface water facilities.

Included in five plans for surface reservoir development is Callahan Reservoir on the Scott River near Callahan. This reservoir could provide a safe yield of about 68,000 acre-feet per season, which could be conveyed northward to serve large acreages of irrigable land in Scott Valley. Several smaller reservoirs for the development of water supplies for local areas within Scott Valley, which were considered, include Highland Reservoir on Moffett Creek, Etna Reservoir on French Creek, Grouse Creek Reservoir on the East Fork of Scott River, and Mugginsville Reservoir on Mill Creek.

The proposed plans represent several alternative possibilities, and not all of the works discussed herein would be required to meet the ultimate supplemental water requirements of the Valley. Further economic and engineering studies would be required prior to selection of the most desirable plan or plans to serve Scott Valley. The locations of these projects are shown on Plate 19, "Existing and Possible Future Developments, Scott Valley".

Scott Valley Ground Water Development. The ground water basin underlying Scott Valley is capable of development to provide water to new irrigable lands as well as to presently irrigated lands.

Estimates indicate that the development of a supplemental water supply from ground water storage, by planned operation of the ground water basin, would require a lesser capital expenditure than development of surface storage projects to provide a comparable amount of water. Furthermore, permanent lowering of the water table in Scott Valley would reduce or eliminate nonbeneficial consumptive use of water by native vegetation, and would make possible increased production of crops on lands presently restricted because of high water table conditions. Additional benefits, although of lesser importance in an area of surplus water supplies, would accrue from the salvage of much of the water supply which would otherwise be lost by evaporation from a surface reservoir.

It was assumed, in formulating a plan of ground water operation, that the responsible operating agency would be an irrigation or similar district, organized to include all of the proposed service area in Scott Valley. The development and use of the ground water basin could be accomplished with the consent and for the benefit of the overlying ground water users, all of whom would be members of the district. Such an organization would avoid involvement in complicated legal restrictions and impediments affecting the use of underground waters. Estimates of cost presented in this section, however, do not include the cost of acquiring existing ground water development facilities nor other costs associated therewith. Such outlays would necessarily have to be determined at such time as ground water operation was undertaken.

The Scott Valley Ground Water Development would supply 50,000 acre-feet of new water seasonally to serve as supplemental water to presently irrigated lands and new water for irrigable lands to be developed in the future. It was assumed that existing surface supplies would continue to be utilized. The estimates of available water supply, both surface and ground water, and water requirements were based on mean conditions of water supply and climate. In actual operation, the requirements and the supply from each source would vary from season to season.

In preparing a plan for ground water development, a number of assumptions regarding the type, capacity, and arrangement of the necessary facilities were made. In this connection, the more important assumptions and criteria used for cost estimating purposes are as follows: 1) The discharge of individual pumping plants was assumed to be within the range of 750 to 1,250 gallons per minute. This assumption was based on specific yields of the few wells now operating in Scott Valley. 2) The average well drawdown at full well discharge capacity was assumed to be 4 feet per 100 gallons per minute of capacity. 3) Wells would be 16 inches in diameter, 125 feet in depth, gravel packed, and cased. 4) Where groups of one to three wells were required to supply a canal, multistage deep-well turbine pumps would lift water directly into the canal. 5) In cases where more than three wells would be required, single stage deep-well turbine pumps would supply water to a small holding reservoir. The water would then be lifted by centrifugal pumps to the canals.

Design capacities of pumping equipment and canals include allowances for canal losses. Canals were trapezoidal in section, unlined, and designed for a slope of 2 feet per mile. Most of the canals were located at a maximum elevation of 3,120 feet, sufficient

to serve most of the irrigable lands. Works for additional lifts to serve lands above the canals were not included.

Topographic and geologic considerations led to the establishment of four subdivisions, or service areas, in Scott Valley. These are designated, respectively, the East Side, West Side, Valley, and Quartz Valley Service Areas. The service areas, and the principal features which would be required for planned ground water development, are shown on Plate 19. A summary of present and ultimate areas of irrigated lands, and the respective supplemental water requirements for each service area, is presented in Table 58. A description of each service area, and the works required to supply supplemenal water from ground water development, is presented in the following sections.

1. *East Side Service Area.* This service area comprises all irrigable lands on the east side of Scott Valley lying generally above the elevation of the Scott Valley Irrigation District Canal. It extends from Callahan on the south to Meamber Creek on the north, with the exception of lands along Moffett Creek. The irrigable lands in this service area consist of a number of separate valleys and gulches, which are drained by intermittent streams flowing into Scott Valley from the low mountains to the east and north. The ultimate net irrigable land within the service area was estimated to be about 7,700 acres, of which about 1,200 acres are presently irrigated. The total ultimate supplemental water requirement was estimated to be about 18,000 acre-feet per season.

Service to the East Side Service Area would be accomplished by nine canals for the distribution of water supplies to the scattered parcels of irrigable land. Nine groups of wells supplying water to the canal system would be located in the higher yielding alluvium found beneath the valley floor.

That portion of the service area northwest of Fort Jones would be served by three canals designated, respectively, Hooperville Canal I, II, and III. These three canals would deliver about 2,900 acre-feet seasonally. The lengths and source of supply for each canal is given in Table 59.

The Hamlin Gulch area, south of Fort Jones, would be served by two canals. The Hamlin North Canal, along the north side of the area, would deliver about 3,400 acre-feet per season. The Hamlin South Canal, located along the south edge of Hamlin Gulch and the east side of Scott Valley, would provide irrigation water to lands above the existing district ditch. Water produced at the well field would be delivered to a small holding reservoir from whence it would be lifted into the Hamlin South Canal.

The Hartstrand Gulch area would be served by two canals. Hartstrand Canal I would deliver water along the northern edge of Hartstrand Gulch, and Hartstrand Canal II would deliver water to the southern portion. The two canals would deliver about 4,800 acre-feet per season.

The McConnahue Gulch area would be served by a canal around the perimeter of the gulch, delivering about 3,100 acre-feet per season to the irrigable lands.

The Messner Canal would extend for about 5 miles along the east side of Scott Valley, in the vicinity of Messner Gulch. About 1,900 acre-feet per season would be delivered by this canal.

A summary of the general features of the works for the ground water development for the East Side Service Area is given in Table 59.

2. *West Side Service Area.* The West Side Service Area includes all of the irrigated and irrigable land on the west side of Scott Valley lying south of Kidder Creek and above an elevation of 2,800 feet. The service area includes a net irrigable area of about 4,000 acres, of which about 1,100 acres are presently irrigated. The ultimate supplemental water requirement resulting from the development of new lands has been estimated to be about 7,500 acre-feet per season. An additional 200 acre-feet of water per season also would be required to meet the increased consumptive use, resulting from an estimated change in the crop pattern, on presently irrigated lands. Six

TABLE 58

PRESENT AND ULTIMATE NET IRRIGATED AREAS AND SUPPLEMENTAL WATER REQUIREMENTS FOR SCOTT VALLEY GROUND WATER DEVELOPMENT SERVICE AREAS

Service area	Net irrigated areas, in acres			Supplemental water requirement, in acre-feet		
	Present net irrigated	Additional net irrigable	Total ultimate net irrigated	Present irrigated lands	Additional irrigable lands	Total supplemental water requirement
East Side	1,200	6,500	7,700	0	17,700	17,700
West Side	1,100	2,900	4,000	200	7,500	7,700
Valley	22,000	3,300	25,300	2,200	8,800	11,000
Quartz Valley	3,200	4,000	7,200	1,000	12,900	13,900
TOTALS	27,500	16,700	44,200	3,400	46,900	50,300

TABLE 59

GENERAL FEATURES OF GROUND WATER DEVELOPMENT IN THE EAST SIDE SERVICE AREA

Item	Canal name and service area								
	Hooperville			Hamlin		Hartstrand			
	I	II	III	North	South	I	II	McConnahue	Messner
Area in acres									
Present net irrigated area	0	0	0	0	0	0	0	800	400
Additional net irrigable area	200	500	100	1,100	1,400	700	900	1,000	600
Ultimate net irrigated area	200	500	100	1,100	1,400	700	900	1,800	1,000
Distribution Canals									
Length, in miles	3.8	8.6	2.9	8.3	16.2	5.5	4.2	7.8	5.4
Capacity, in second-feet	2.2	6.3	1.6	11.7	17.5	7.3	9.5	10.9	6.6
Total seasonal supplemental water delivered, in acre-feet	500	1,400	400	2,900	3,900	1,800	2,500	2,700	1,600
Approximate initial elevation, in feet	2,880	3,120	2,880	3,120	3,120	3,120	2,960	3,120	3,120
Well Fields and Pumps									
Number of wells	1	2	1	4	6	3	3	4	2
Number of booster pumps	----	----	----	----	6	----	----	----	----
Total capacity, in gallons per minute	1,000	3,000	750	5,250	7,750	3,250	4,250	5,000	3,000
Water pumped, in acre-feet per season	635	1,820	460	3,370	5,060	2,100	2,740	3,150	1,900
Length of pipe lines, in feet	640	3,950	1,100	6,250	5,400	2,900	3,700	5,000	1,700
Reservoir capacity, in acre-feet	----	----	----	----	1.4	----	----	----	----
Total pumping head, in feet	270	550	200	470	400	430	315	345	320
Total installed horsepower	100	600	50	850	1,125	500	450	600	300
Electric energy, in kilowatt-hours per year	228,000	1,308,000	119,000	2,033,000	5,918,000	1,184,000	1,150,000	1,422,000	799,000

distribution canals, two well fields, and one pumping plant are proposed to supply water to the irrigable lands of the West Side Service Area.

Water supplies for that part of the West Side Service Area lying between Etna Creek and Kidder Creek would be developed in conjunction with water supplies for the portion of the Valley Service Area lying west of Scott River. A group of 13 wells would be located in the central part of the valley east of Etna, and would provide a combined capacity of 16,250 gallons per minute. A total of 8,900 acre-feet of water per season would be produced by these wells, of which 5,000 acre-feet would be delivered to lands in the West Side Service Area and the remainder to lands in the Valley Service Area. From the proposed Greenview Reservoir, located on Greenview Canal about 1.5 miles north of Etna, water supplies for the West Side Service Area would be pumped to the Etna North and South Canals. About 1,300 acre-feet of water per season would be delivered by the South Canal, and about 3,700 acre-feet per season by the Etna North Canal.

That portion of the West Side Service Area lying south of Etna Creek would be served by two canal systems. North and South French Creek Canals would serve a combined total of about 2,400 acre-feet of water per season, and North and South Sugar Creek Canals would deliver a total of about 1,300 acre-feet of water per season to irrigable lands lying east of the canal systems.

A summary of the general features of the works required for the ground water development of the West Side Service Area is given in Table 60.

3. *Valley Service Area.* This service area comprises the main valley floor between Clarks Creek, about 2 miles south of Etna, and Meamber Creek, about 7 miles west of Fort Jones, and extends from the Scott Valley Irrigation District Canal on the east to the edge of the valley floor on the west. The service area overlies nearly all of the Scott Valley ground water basin, described in Chapter II. The ground water development plan assumes the establishment of well fields in the higher yielding alluvium, together with a conveyance system to serve other portions of the service area.

The Valley Service Area contains a net irrigable area of approximately 25,400 acres, of which about 22,000 acres are presently irrigated, principally from surface sources. The ultimate supplemental water requirement has been estimated to be 11,000 acre-feet per season. This would provide 8,800 acre-feet of water per season to provide for the development of new lands, and 2,200 acre-feet to meet increased consumptive use resulting from probable changes in the crop pattern on presently irrigated lands.

Water supplies required for both the Valley and the adjacent West Side Service Areas would be developed by the establishment of a well field, east of Etna, in the central part of the valley. This field would con-

sist of thirteen 1,250-gallon-per-minute wells, capable of supplying a total of 8,900 acre-feet of water during the irigation season. About 5,000 acre-feet of water would be repumped from a regulating reservoir in the Greenview I Canal to the Etna Canal system in the West Side Service Area.

About 3,900 acre-feet of water per season, including allowances for seepage losses from canals, would be produced from ground water to meet water requirements of the Valley Service Area. In addition, surface return flows emanating from the East Side and West Side Service Areas would be diverted and distributed through the Valley Service Area canals. The quantities diverted, together with the supply available from ground water, would be sufficient to provide for the delivery of 5,700 acre-feet per season from the Greenview Canal system, and 5,300 acre-feet per season from the existing Scott Valley Irrigation District Canal.

The existing Scott Valley Irrigation District Canal, with some improvement, would be used to distribute water supplies to the lands east and north of Scott River. The Greenview I and Greenview II Canals would serve lands lying to the west of Scott River.

General features of the ground development works and distribution facilities for the Valley Service Area are given in Table 61.

4. *Quartz Valley Service Area.* This area comprises the irrigated and irrigable lands in Quartz Valley, Oro Fino Valley, and lands north of Kidder Creek. The net irrigable area amounts to 7,100 acres, of which about 3,200 acres are presently irrigated. The ultimate supplemental water requirement was estimated to be 13,900 acre-feet, including about 1,000 acre-feet required by presently irrigated lands to meet increased consumptive use resulting from changes in crop pattern. The estimated water requirement for lands lying in Quartz Valley and north of Kidder Creek was 11,600 acre-feet. The remainder of the supplemental water requirement, 2,300 acre-feet, would be used in Oro Fino Valley.

Quartz Valley lands would be served by two canal systems, the Lower Quartz Valley Canal, serving lands below an elevation of 2,880 feet, and the Upper Quartz Valley Canal, serving the remainder of the irrigable lands, lying between elevations of 3,120 and 2,880 feet. The Lower Quartz Valley Canal would receive and distribute water pumped from a well field which, based on geologic reconnaissance, would appear to be located in an area of high ground water yield.

Irrigable lands lying at higher elevations in Quartz Valley, as well as irrigable lands in Oro Fino Valley, would receive water pumped from a well field located north of Scott River near the confluence of Oro Fino Creek and Scott River. A small regulating reservoir would be located south of Scott River, from which water would be lifted to the Lower Oro Fino Canal. The canal would extend southward about 6 miles and would serve about 1,900 acre-feet of water per season to lands in Oro Fino Valley. At the terminus of the canal, water would again be lifted to an elevation of 3,120 feet. From this point, the Upper Oro Fino Canal would convey about 3,800 acre-feet per season southward to lands west of Kidder Creek, and the Upper Quartz Valley Canal would distribute about 5,200 acre-feet per season to higher lands in Quartz Valley.

TABLE 60

GENERAL FEATURES OF GROUND WATER DEVELOPMENT IN THE WEST SIDE SERVICE AREA

Item	Canal name and service area					
	Etna		French Creek		Sugar Creek	
	North	South	North	South	North	South
Area, in acres						
Present net irrigated area	200	100	200	100	100	100
Additional net irrigable area	1,200	500	300	500	100	300
Total ultimate net irrigated area	1,400	600	500	900	200	400
Distribution canals						
Length, in miles	5.6	2.3	3.6	6.4	0.6	9.2
Capacity, in second-feet	12.7	4.5	3.3	5.4	0.6	4.0
Total seasonal supplemental water delivered, in acre-feet	3,300	1,200	900	1,300	100	900
Approximate initial elevation, in feet	3,040	3,040	3,120	3,120	3,120	3,120
Well Fields and Pumps						
Number of wells	(See Valley Service Area)		3		2	
Number of booster pumps	5					
Total capacity, in gallons per minute	8,100		3,750		2,000	
Water pumped, in acre-feet per season	5,000		2,100		1,300	
Length of pipe lines, in feet	8,900		3,700		1,800	
Reservoir capacity, in acre-feet	0.9					
Pumping head, in feet	260		380		310	
Total installed horsepower	750		450		200	
Electric energy, in kilowatt-hours per year	2,013,000		1,190,000		511,200	

The Tuttle Gulch area on the north side of Quartz Hill would be served by the Tuttle Gulch Canal, distributing about 800 acre-feet of water per season to irrigable lands in the area.

General features of the works required for the ground water development in the Quartz Valley Service Area are given in Table 62.

5. *Summary.* The Scott Valley Ground Water Development would include 64 wells and pumps, 10 miles of pipe lines, 4 booster pumping plants, and 160 miles of canals. An average of about 53,000 acre-feet would be pumped from the ground water. Allowing for water lost from canals as well as some reuse of return flows, about 50,000 acre-feet of supplemental water would be delivered. The capital cost of the works comprising the project is estimated to be about $3,278,000. The annual cost, including cost of electric energy for pumping, would be about $390,000. The average cost of development would be about $8 per acre-foot. However, the cost of water from individual pump and canal systems would vary from $3 per acre-foot to $11 per acre-foot. It should be noted that main conveyance canals are included in these costs while canals are not included in subsequent discussions of surface storage reservoirs. A summary of capital and annual costs for each of the separate canals in the system is shown in Table 63.

Highland Dam and Reservoir. Highland Dam and Reservoir, on Moffett Creek about five miles east of Fort Jones, would provide a water supply to meet supplemental water requirements in the Moffett Creek service area. The dam would be located in Section 2, Township 43 North, Range 8 West, M.D.B.&M. The location of the reservoir is shown on Plate 19 and the principal features of the dam are shown on Plate 23.

TABLE 61

GENERAL FEATURES OF GROUND WATER DEVELOPMENT IN THE VALLEY SERVICE AREA

Item	Canal name and service area		
	Greenview		Scott Valley Irrigation District Canal
	I	II	
Area, in acres			
Present net irrigated area	15,200		6,800
Additional net irrigable area	1,200		2,100
Total ultimate net irrigated area	16,400		8,900
Distribution canals			
Length, in miles	16.7		24.5
Capacity, in second-feet	30-12		77-13
Total seasonal supplemental water delivered, in acre-feet	[1]5,700		[1]5,300
Approximate initial elevation, in feet	2,800		2,790
Well fields and pumps			
Number of wells		13	
Number of booster pumps		none	
Total capacity, in gallons per minute		16,250	
Water pumped, in acre-feet per season		[2]8,900	
Length of pipe lines, in feet		4,550	
Reservoir capacity, in acre feet		none	
Pumping head, in feet		60	
Total installed horsepower		325	
Electric energy, in kilowatt-hours per year		726,300	

[1] Includes return water from East and West Side Service Areas.
[2] Includes capacity for delivery of 5,000 acre-feet per season to West Side Service Area.

TABLE 62

GENERAL FEATURES OF GROUND WATER DEVELOPMENT IN THE QUARTZ VALLEY SERVICE AREA

Item	Canal name and service area				
	Quartz Valley		Oro Fino Valley		Tuttle Gulch
	Lower	Upper	Upper	Lower	
Area, in acres					
Present net irrigated area	1,200	700	400	900	0
Additional net irrigable area	1,000	1,400	1,000	400	200
Ultimate net irrigated area	2,200	2,100	1,400	1,300	200
Distribution Canals					
Length, in miles	5.7	7.4	4.1	5.9	3.9
Capacity, in second-feet	10	18	13	7	3
Total seasonal supplemental water delivered, in acre-feet	3,500	4,600	3,500	1,700	600
Approximate initial elevation, in feet	2,880	3,120	3,120	2,880	2,880
Well Fields and Pumps					
Number of wells	6	----	13	----	1
Number of booster pumps	----	5	----	5	----
Total capacity, in gallons per minute	5,750	14,000	17,000	17,000	1,250
Water pumped, in acre-feet per season	3,700	----	10,900	----	800
Length of pipe lines, in feet	400	1,300	12,500	1,250	900
Reservoir capacity, in acre-feet	----	1.5	----	3.6	----
Pumping head, in feet	50	260	75	280	250
Total installed horsepower	110	1,200	450	1,050	100
Electric energy, in kilowatt-hours per year	240,000	3,256,000	984,500	3,140,000	270,000

TABLE 63

SUMMARY OF ESTIMATED CAPITAL AND ANNUAL COSTS SCOTT VALLEY GROUND WATER DEVELOPMENT

Service area and canal	Capital cost	Annual cost
East Side Service Area		
Hooperville I	$36,000	$4,000
Hooperville II	181,000	20,000
Hooperville III	29,000	3,000
Hamlin North	276,000	32,000
Hamlin South	462,000	49,000
Hartstrand I	145,000	19,000
Hartstrand II	142,000	18,000
McConnahue	221,000	25,000
Messner	91,000	13,000
Subtotals	$1,583,000	$183,000
West Side Service Area		
Etna North	274,000	31,000
Etna South	79,000	10,000
French Creek North, French Creek South	158,000	19,000
Sugar Creek North, Sugar Creek South	99,000	10,000
Subtotals	$610,000	$70,000
Valley Service Area		
Greenview I	$8,000	$1,000
Greenview II	163,000	17,000
Subtotals	$171,000	$18,000
Quartz Valley Service Area		
Lower Quartz Valley	92,000	10,000
Upper Quartz Valley	428,000	54,000
Upper Oro Fino	270,000	37,000
Lower Oro Fino	85,000	11,000
Tuttle Gulch	39,000	5,000
Subtotals	$914,000	$117,000
TOTALS	$3,278,000	$388,000

Highland Reservoir would provide an estimated safe yield of about 9,800 acre-feet per season. Although no specific service area has been designated, the project could provide irrigation water service to about 2,500 acres. Much of the yield would be new water, since unregulated flows of Moffett Creek below the dam site are small during years of subnormal water supply conditions. It is estimated that about 2,000 acre-feet of runoff occurred during the irrigation season, April to October, in 1934, with flows of less than 100 acre-feet per month from July through October. A monthly yield study for the period 1920-21 through 1951-52 is presented in Appendix E.

Preliminary geologic reconnaissance indicates that the Highland dam site is suitable for an earthfill structure about 160 feet in height. Although the abutment slopes are gentle, they are very irregular and deeply gullied. At the site, the channel of Moffett Creek is incised about eight feet below the broad flood plain. Bedrock consists of a metamorphic (probably metasedimentary) series of hard and resistant rocks, lightly jointed and sheared. These rocks are consistently foliated and, except in areas of local distortion, strike roughly perpendicular to the direction of the channel and dip about 60 degrees upstream.

A sufficient quantity of material from the channel fill and from soil deposits near the bottom of the hill slopes is available within a mile radius of the dam site for construction of the impervious section of the dam. Selective borrow operations would be required in the channel to separate the soil from the interlayered gravels. Soil tests have determined that the material is a brown silty sand of fair quality for construction of an impervious embankment. Local bedrock could be quarried for use either as pervious fill, rockfill, or riprap, as needed. With proper treatment, the stream bed gravels would be suitable for filters and drains.

For estimating purposes the dam has been designed as an earthfill structure, 160 feet in height, with a crest length of 1,040 feet and a normal pool storage capacity of 26,000 acre-feet. The spillway has been designed for a discharge of 4,500 second-feet. The outlet works would be located in the left abutment and would consist of a 30-inch steel pipe encased in concrete and provided with control valves.

Highland Reservoir would inundate about 460 acres at the normal water surface elevation of 3,394 feet. The reservoir area contains less than 100 acres of irrigated lands. The remaining area is dry-farmed land and unimproved hill lands. There are several ranch houses and a small school building in the reservoir area. The Moffett Creek and Duzel Creek Roads would require relocation around the reservoir, as would power and telephone lines. Table 64 shows the area and storage capacities at various pool elevations.

Pertinent data with respect to general features of Highland Dam and Reservoir as designed for cost estimating purposes are presented in Table 65.

The capital cost of Highland Dam and Reservoir was estimated to be about $4,092,000, and the corresponding annual cost was estimated to be $195,000. The average cost of development of 9,800 acre-feet per season, not considering cost allocation or possible non-reimbursable costs, would be about $20.00 per acre-foot. A detailed cost estimate is presented in Appendix F.

TABLE 64

AREAS AND CAPACITIES OF HIGHLAND RESERVOIR

Depth of water at dam, in feet	Water surface elevation, USGS datum in feet	Water surface area, in acres	Storage capacity, in acre-feet
0	3,245	0	0
15	3,260	10	78
35	3,280	50	680
55	3,300	86	2,040
75	3,320	141	4,310
95	3,340	207	7,790
115	3,360	311	13,000
135	3,380	402	20,100
149	3,394	460	26,200
155	3,400	490	29,000

TABLE 65

GENERAL FEATURES OF HIGHLAND DAM AND RESERVOIR

Dam	
Type	earthfill
Crest elevation, in feet	3,405
Crest length, in feet	1,040
Crest width, in feet	30
Height, spillway lip above stream bed, in feet	149
Side slopes, upstream	2:1
downstream	2:1
Freeboard above spillway lip, in feet	11
Stream bed elevation, in feet	3,245
Volume of fill, in cubic yards	1,772,000
Reservoir	
Surface area at spillway lip, in acres	460
Storage capacity at spillway lip, in acre-feet	26,200
Drainage area, in square miles	60
Estimated average seasonal runoff, in acre-feet	13,100
Estimated safe seasonal yield, in acre-feet	9,800
Type of spillway—ungated, concrete ogee weir with concrete-lined approach and discharge aprons	
Type of outlet—30-inch diameter concrete-encased steel pipe beneath dam	

Callahan Dam and Reservoir. Callahan Dam and Reservoir would develop sufficient water supplies to meet the ultimate requirements of that portion of Scott Valley situated north of the town of Callahan. The reservoir would provide a regulated irrigation water supply that could be delivered by gravity to most of the area, and would firm releases to Scott River below the dam for maintenance of the fishery. It would also provide a measure of flood control protection to low lying areas in Scott Valley.

The reservoir would be located on Scott River less than one mile north of the town of Callahan, in Section 17, Township 40 North, Range 8 West, M.D.B.&M. The location of the dam and reservoir is shown on Plate 19, and the principal features of the dam are delineated on Plate 23.

Callahan Reservoir would provide an estimated safe yield of about 77,500 acre-feet seasonally, including an average stream flow maintenance release of 22 second-feet. An allocation of 15,000 acre-feet of storage space for flood control operation during the period from November 1st to April 1st would prevent flood waters of the East and South Forks of Scott River from entering the valley floor during high runoff periods. A monthly yield study for the period 1921-22 through 1951-52, utilizing estimates of the present impaired flow of the Scott River below the juncture of the East and South Forks, is presented in Appendix E.

Based on preliminary geologic reconnaissance, the Callahan dam site appears suitable for an earthfill dam about 280 feet in height. The left abutment is moderately steep and of a uniform slope, with the right abutment flatter in slope and very irregular. The channel section is broad, flat, and choked with dredger tailings. Several terraces occur at the lower elevations, especially on the right abutment.

There are relatively few bedrock outcrops. The principal rock underlying the site appears to be a hard, moderately jointed, varicolored chert. This is associated with other rocks, chiefly metasediments, which have widely varying characteristics. It may also be found, upon further study, that igneous rocks occur in the foundation area. Jointing is prominent and occurs in well-defined sets. No important shears or faults were seen during the field inspection.

It appears likely that sufficient impervious material could be obtained within a few miles by stripping large areas having relatively thin soil cover. However, considerably more exploration and testing of the impervious fill materials would be required. The vast deposits of dredger tailings found in this vicinity would provide ample material for the pervious zones of the dam.

The proposed dam would be about 280 feet in height, with a crest length of 1,940 feet, and a normal pool storage capacity of 133,000 acre-feet. The spillway would be designed for a discharge of about 13,000 second-feet. The outlet works for irrigation, flood control, and stream flow maintenance releases would consist of a steel pipe placed in a tunnel through the right abutment. This tunnel would be used for diversion of the stream during construction. Irrigation water would be diverted into canals on the east and west sides of the river for conveyance to the service area. However, no estimates of the cost of the conveyance system were made.

Callahan Reservoir would inundate an area of 1,469 acres at normal water surface elevation of 3,355 feet. Table 66 presents data on the water surface area and reservoir storage capacity for various pool elevations in the reservoir. The area that would be flooded by the reservoir contains the town of Callahan, and a United States Forest Service ranger station. Timber cover in the reservoir area is light, and the land is used principally for grazing. About 4 miles of paved road and 3 miles of graded dirt road within the reservoir area would require relocation.

Pertinent data with respect to general features of Callahan Dam and Reservoir, as developed for cost estimating purposes, are presented in Table 67. De-

TABLE 66

AREAS AND CAPACITIES OF CALLAHAN RESERVOIR

Depth of water at dam, in feet	Water surface elevation, U.S.G.S. datum, in feet	Water surface area, in acres	Storage capacity, in acre-feet
0	3,095	0	0
50	3,145	121	1,900
100	3,195	320	12,900
150	3,245	548	34,200
200	3,295	918	66,200
250	3,345	1,370	108,800
260	3,355	1,469	133,000

tailed estimates of the cost of the dam and reservoir are presented in Appendix F.

The capital cost of the dam and reservoir was estimated to be about $10,900,000. The annual cost, including amortization, operation, and maintenance, was estimated to be about $522,000. The average cost of development of about 77,500 acre-feet per season of firm yield would be about $6.80 per acre-foot. This does not include costs of conveyance canals. No consideration was given to cost allocation or to possible non-reimbursable costs.

TABLE 67

GENERAL FEATURES OF CALLAHAN DAM AND RESERVOIR

Dam	
Type	earthfill
Crest elevation, in feet	3,366
Crest length, in feet	1,940
Crest width, in feet	40
Height, spillway lip above stream bed, in feet	265
Side slopes, upstream	3:1
downstream	2.5:1
Freeboard above spillway lip, in feet	11
Elevation of stream bed, in feet	3,090
Volume of fill, in cubic yards	9,560,000
Reservoir	
Surface area at spillway lip, in acres	1,469
Storage capacity at spillway lip, in acre-feet	133,000
Drainage area, in square miles	160
Estimated average seasonal runoff, in acre-feet	99,300
Estimated safe seasonal yield, including fishing release, in acre-feet	71,400
Type of spillway	uncontrolled ogee weir and lined chute across right abutment
Spillway discharge capacity, in second-feet	12,900
Type of outlet works	48-inch diameter pipe inside tunnel through right abutment

Grouse Creek Dam and Reservoir. Grouse Creek Dam and Reservoir would be located on the East Fork of Scott River about 4 miles east of Callahan and just upstream from the mouth of Grouse Creek, in Section 19, Township 40 North, Range 7 West, M.D.B.&M. The reservoir would develop water for irrigation in Scott Valley. The regulated water would be released into the stream channel and diverted downstream into ditches for conveyance to irrigable lands. The location of the reservoir is shown on Plate 19 and the principal features of the dam are shown on Plate 23.

The reservoir at this site was considered as an alternative to Callahan Reservoir. Grouse Creek Reservoir would avoid flooding the town of Callahan and would require less highway relocation. The yield obtainable, however, would be less since only the waters of the East Fork of the Scott River would be regulated. A reservoir at this site, with a storage capacity of 50,000 acre-feet, would have a safe seasonal yield of 20,000 acre-feet. Based on a yield study for the 32-year period, 1920-21 through 1951-52, as shown in Appendix E, this yield would be available each season except in 1933-34, when a 35 per cent deficiency would be experienced.

From a geologic reconnaissance exploration, Grouse Creek dam site was found to be suitable for either an earth- or rock-fill dam of a height of 175 feet. The abutments are moderately steep, with about a 30 per cent slope on the left abutment and a 50 per cent slope on the right abutment. The rock at the site is peridotite, probably of Jurassic age, partially altered to serpentine. Numerous outcrops occur on both abutments, and much of the abutment area is covered with loose talus. Jointing in the rock is prominent in outcrops and in the road cut on the lower left abutment, but appears to tighten at depth.

Many shear planes, up to several inches in width, occur and are usually filled with crushed serpentine. In general, from surface evidence, serpentinization of the peridotite is not advanced. However, drilling would be required to determine subsurface conditions. It appears that moderate to heavy grouting would be required. In the channel section, rock outcrops occur at both edges of the 120-foot wide channel. From dredging evidence upstream, the depth of gravel fill is estimated to be 12 feet, but it could exceed that figure if an older and deeper channel exists at the site.

There is a limited amount of impervious fill material available within the reservoir site, and additional material could be obtained from Noyes Creek Valley within a distance of 2 miles. A considerable amount of gravel could be obtained from the reservoir area. Most of the rock excavated for stripping and for the spillway could be used in the dam.

Cost estimates were based on preliminary designs for an earthfill structure 175 feet in height from stream bed to crest of dam, with a crest length of 1,225 feet, and a normal pool storage capacity of 50,000 acre-feet. The spillway would be designed for a discharge capacity of 6,000 second-feet. The outlet works, beneath the dam in the right abutment, would consist of a 42-inch steel pipe encased in concrete and provided with appurtenant valves.

The reservoir area covers about 800 acres of land, including about 330 acres of irrigated meadow land and 60 acres of irrigable land. The remaining area is undeveloped and is covered by forest or brush. Improvements that would be inundated include about 12 ranch or farm buildings and about three miles of unpaved county roads. Table 68 presents the water surface area and storage capacity for various pool elevations in the reservoir.

Pertinent data with respect to the general features of Grouse Creek Dam and Reservoir, as designed for cost estimating purposes, are presented in Table 69. Detailed estimates of the dam and reservoir are presented in Appendix F.

The capital cost of Grouse Creek Dam and Reservoir was estimated to be about $4,130,000, and the corresponding annual cost was estimated to be $200,000. The cost of development of a firm yield of 20,000 acre-

feet per season would be about $10 per acre-foot at the dam. No consideration was given to cost allocation or non-reimbursable funds for items such as recreation and flood control.

TABLE 68

AREAS AND CAPACITIES OF GROUSE CREEK RESERVOIR

Depth of water at dam, in feet	Water surface elevation, U.S.G.S. datum, in feet	Water surface area, in acres	Storage capacity, in acre-feet
0	3,500	0	0
25	3,525	30	400
50	3,550	120	2,350
75	3,575	220	6,600
100	3,600	350	13,700
125	3,625	490	24,200
150	3,650	650	38,600
166	3,666	770	50,000
175	3,675	860	57,400

TABLE 69

GENERAL FEATURES OF GROUSE CREEK DAM AND RESERVOIR

Dam

Type	earthfill
Crest elevation, in feet	3,675
Crest length, in feet	1,225
Crest width, in feet	15
Height, spillway lip above stream bed, in feet	166
Side slopes, upstream	3:1
downstream	2:1
Freeboard above spillway lip, in feet	9
Stream bed elevation, in feet	3,500
Volume of fill, in cubic yards	1,975,000

Reservoir

Surface area at spillway lip, in acres	800
Storage capacity at spillway lip, in acre-feet	50,000
Drainage area, in square miles	57
Estimated average seasonal runoff, in acre-feet	25,000
Estimated safe seasonal yield, in acre-feet	20,000
Type of spillway	ungated side channel spillway with lined chute
Spillway discharge capacity, in second-feet	6,000
Type of outlet	42-inch steel pipe encased in concrete beneath dam in right abutment

Etna Dam and Reservoir. Etna Dam and Reservoir, on French Creek about four miles south of the town of Etna, would provide new water supplies in addition to the present unregulated diversions for irrigation use to areas adjacent to French Creek in Scott Valley. Etna Dam would be located in Section 15, Township 41 North, Range 9 West, M. D. B. & M. The location of the reservoir is shown on Plate 19 and the principal features of the dam are shown on Plate 24.

Etna Reservoir would provide an estimated safe seasonal yield of 11,000 acre-feet. During the 32-year period, 1920-21 through 1951-52, the yield would be firm and the reservoir would spill each season, except for the season 1923-24 when the firm yield would be reduced to 7,000 acre-feet. Most of the yield would be new water, since the reservoir would fill to capacity prior to the beginning of the irrigation season and the unregulated water occurring during the irrigation season would still be available for diversion. A larger reservoir could be considered at this site, although the cost of additional increments of yield would be expensive. A seasonal summary of the yield study is presented in Appendix E.

The Etna dam site was found from reconnaissance geologic exploration to be suitable for an earthfill dam about 90 feet in height. The site is located near the mouth of the broad, flat-bottomed valley of French Creek and has relatively gentle abutment slopes. The right abutment slope, however, is somewhat irregular due to the ragged, blocky outcrops of bedrock. Partially serpentinized, ultra-basic igneous rock underlies the site and outcrops in both abutments. The rock is prominently jointed, but the joints appear to be shallow and tight. Shear zones are numerous although they appear to be tight.

Alluvial silts and soils, suitable for use as impervious fill, may be obtained in Scott Valley within one mile of the Etna site. Similar materials in thinner layers may be obtained from flats of the reservoir area with a slightly increased average haul distance. This latter source would probably involve much wet excavation and drying of impervious fill prior to placing in the dam. Sands and gravels for pervious embankment sections could be obtained from the channel section at and within one mile of the site. Dredger tailings are available in Scott River in virtually unlimited quantities at a distance of slightly over two miles. Rock for riprap may be quarried locally.

The proposed dam would be 87 feet in height from stream bed to crest of the dam, with a crest length of 1,900 feet, and a normal pool storage capacity of 12,000 acre-feet. The spillway would be designed for a discharge of 12,500 second-feet. The outlet works beneath the dam in the right abutment would consist of a 42-inch steel pipe encased in concrete and provided with appurtenant valves.

The reservoir area, covering a total of about 300 acres, includes about 130 acres of irrigated land and about 100 acres of irrigable land. Most of the remaining area is brush and forest land. Improvements that would be inundated include a sawmill and several residences and ranch buildings. About two miles of county road would require relocation as would telephone and power lines. Table 70 presents the water surface area and storage capacity for various pool elevations in the reservoir.

Pertinent data with respect to general features of Etna Dam and Reservoir, as designed for cost estimating purposes, are presented in Table 71. A detailed estimate for cost is presented in Appendix F.

The capital cost of Etna Dam and Reservoir was estimated to be about $2,640,000, and corresponding annual costs were estimated to be about $125,000. The cost of development of a firm yield of 11,000 acre-feet per season would be about $11.50 per acre-foot at the dam.

TABLE 70

AREAS AND CAPACITIES OF ETNA RESERVOIR

Depth of water at dam, in feet	Water surface elevation, U.S.G.S. datum, in feet	Water surface area, in acres	Storage capacity, in acre-feet
0	2,855	0	0
5	2,860	35	200
15	2,870	72	700
25	2,880	110	1,600
35	2,890	145	2,900
45	2,900	180	4,500
55	2,910	212	6,400
65	2,920	253	8,700
75	2,930	290	11,400
77	2,932	295	12,000
85	2,940	328	14,600

TABLE 71

GENERAL FEATURES OF ETNA DAM AND RESERVOIR

Dam	
Type	earthfill
Crest elevation, in feet	2,942
Crest length, in feet	1,900
Crest width, in feet	15
Height, spillway lip above stream bed, in feet	77
Side slopes, upstream	3:1
downstream	2:1
Freeboard above spillway lip, in feet	10
Stream bed elevation, in feet	2,855
Volume of fill, in cubic yards	1,040,000
Reservoir	
Surface area at spillway lip, in acres	295
Storage capacity at spillway lip, in acre-feet	12,000
Drainage area, in square miles	29
Estimated average seasonal runoff, in acre-feet	38,600
Estimated safe seasonal yield, in acre-feet	11,000
Type of spillway	ungated ogee weir with lined chute through right abutment
Spillway discharge capacity, in second-feet	12,500
Type of outlet	one 42-inch steel pipe encased in concrete in right abutment

Mugginsville Dam and Reservoir. Mugginsville Dam and Reservoir would impound the flows of Mill Creek, as well as surplus water diverted from Shackleford Creek, and would provide a safe seasonal yield of 16,000 acre-feet to lands in Quartz Valley, Oro Fino Valley, and in the vicinity of Greenview. Most of the yield would be new water, and the unregulated water presently diverted from these streams would continue to be available. A seasonal summary of a monthly yield study for the period 1920-21 through 1951-52, utilizing estimates of the natural flow of Mill and Shackleford Creeks, is presented in Appendix E.

Mugginsville Dam would be located on Mill Creek, about ¾-mile northwest of Mugginsville, in the southern end of Quartz Valley. The dam site is located in Sections 14 and 15, Township 43 North, Range 10 West, M. D. B. & M. The stream bed elevation at the dam site is 2,853 feet. The location of the reservoir is shown on Plate 19 and the general features are delineated on Plate 24.

The reservoir is advantageously located to receive and regulate water diverted from Shackleford Creek. Although it could also receive water from Kidder Creek, no diversion from the latter stream was included in the proposed project. The excess flows of Mill and Shackleford Creeks would be stored in Mugginsville Reservoir for release by gravity to lands in Quartz Valley. About one-half of the seasonal yield would be lifted by a pumping plant at the base of the dam and would be conveyed southward by a canal which would pass through a short tunnel to deliver water to Oro Fino Valley.

Based on preliminary geologic reconnaissance and consideration of available construction materials, the Mugginsville site would be suitable for a low earthfill dam. However, special attention should be given to the design of the dam since the dam site extends about one mile across a broad alluvium-filled valley where the water table has been found to be within four feet of the surface. The channel of Mill Creek is very close to the right abutment.

The right abutment slopes evenly at about 15 per cent, while to the left of the channel the valley floor has a gentle upward slope of about two per cent with no steep abutment within the limits of the proposed height of dam. The only apparent rock is on the right abutment, where hard metamorphosed volcanic greenstone, veined with quartz, occurs in outcrops. The left half of the dam site is covered by a fairly heavy growth of small pine trees and has not been thoroughly investigated for rock conditions.

There appear to be ample quantities of impervious and semi-pervious embankment material available within the reservoir area. Some selective borrow operations may be required to separate layers of fine soil from intermixed gravel layers. Large quantities of clean gravel are available about five miles downstream from the site in the Scott River channel. Portions of the spoil from stripping operations could be used for both pervious and impervious fill.

Diversions from Shackleford Creek into Mugginsville Reservoir would be made at a low diversion dam which would be located in Section 9, Township 43 North, Range 10 West, M. D. B. & M. The diverted water would be conveyed to the reservoir through a concrete lined canal about 1.5 miles in length.

The proposed Mugginsville Dam would be an earthfill structure 103 feet in height from stream bed to crest of dam, with a crest length of 5,700 feet, and a normal pool storage capacity of 23,000 acre-feet. The spillway would be designed for a discharge capacity of 5,600 second-feet with 6 feet of freeboard remaining on the dam. Two outlet pipes consisting of steel pipe encased in concrete would be provided. One in the left abutment, at a location dependent upon foundation conditions, would provide releases to a canal to serve lands on the west side of Quartz Valley. The main outlet, in the right abutment, would provide releases to the Mill Creek stream channel and Quartz Valley canals. Water to be diverted would pass

through a pumping plant comprised of four centrifugal pumps with a combined discharge capacity of 30 second-feet. The water would be lifted to elevation 2,975 feet and would then flow southward by gravity through two miles of concrete-lined canal and one-half mile of tunnel to Oro Fino Valley. Estimates of cost presented below do not include costs of a distribution system beyond the southern tunnel portal.

Mugginsville Reservoir would inundate an area of about 750 acres at normal water surface elevation. The reservoir area contains about 400 acres of irrigated land. The remaining land, all of which is irrigable, is either dry-farmed agricultural land or wooded area. Several ranch houses and the small settlement of Mugginsville would be flooded by the reservoir. About one mile of paved county road and about 1.5 miles of unpaved road would require relocation. Telephone and power lines through the reservoir area would be rerouted. Table 72 gives the water surface area and storage capacity for various elevations in the reservior.

Pertinent data with respect to the general features of Mugginsville Dam and Reservoir, as designed for cost estimating purposes, are presented in Table 73. A detailed cost estimate is presented in Appendix F.

The capital cost of Mugginsville Dam and Reservoir, including the Shackleford Creek Diversion, was estimated to be $6,724,000. The corresponding annual cost would be $323,000. The cost of development of a firm yield of 16,000 acre-feet per season would be about $20.00 per acre-foot.

Developments on Trinity and Salmon Rivers

The probable ultimate seasonal water requirements for Hydrographic Units 8 through 12 have been estimated to be 149,000 acre-feet. This water would be required primarily for irrigable lands in scattered small tracts adjacent to principal streams. Water resource developments for these lands would very likely consist of small storage dams on tributary creeks, and gravity and pump diversions from perennial streams. This type of development would probably be accomplished by individuals as well as by public agencies.

TABLE 72

AREAS AND CAPACITIES OF MUGGINSVILLE RESERVOIR

Depth of water at dam, in feet	Water surface elevation, U.S.G.S. datum, in feet	Water surface area, in acres	Storage capacity, in acre-feet
0	2,853	0	0
27	2,880	70	700
47	2,900	200	3,400
67	2,920	360	8,900
87	2,940	650	19,000
93	2,946	760	23,000

An exception, however, is Hayfork Valley. A tract in this valley, consisting of nearly 5,000 acres of irrigable land, could be served from a storage dam on Hayfork Creek. Layman Dam and Reservoir would provide new water for the ultimate irrigation requirements of Hayfork Valley and for urban, industrial, and recreation purposes. A second proposed project is Morehouse Dam and Reservoir on the Salmon River, a project primarily for generation of hydroelectric power. These two projects are discussed in the following sections.

Layman Dam and Reservoir. Layman Reservoir would be created by construction of a dam on Hayfork Creek, approximately 1 mile upstream from its junction with Carr Creek. Water impounded by the reservoir would be utilized for irrigation, industrial,

TABLE 73

GENERAL FEATURES OF MUGGINSVILLE DAM AND RESERVOIR

Dam	
Type	earthfill
Crest elevation, in feet	2,956
Crest length, in feet	5,670
Crest width, in feet	30
Height, spillway lip above stream bed, in feet	93
Side slopes, upstream	3:1
downstream	2:1
Freeboard above spillway lip, in feet	10
Stream bed elevation, in feet	2,853
Volume of fill, in cubic yards	2,910,000
Reservoir	
Surface area at spillway lip, in acres	750
Storage capacity at spillway lip, in acre-feet	23,000
Drainage area, in square miles	13
Estimated average seasonal runoff, in acre-feet	8,300
Estimated average seasonal import, in acre-feet	10,900
Estimated safe seasonal yield, in acre-feet	16,000
Type of spillway	ungated ogee weir with lined chute through right abutment
Spillway discharge capacity, in second-feet	5,600
Type of outlet	one 42-inch steel pipe in right abutment, one 24-inch steel pipe in left abutment, both encased in concrete
Diversion Dam	
Type	concrete gravity with wood flashboards
Crest elevation, in feet	2,980
Height, crest above stream bed, in feet	10
Diversion Canal	
Type	concrete-lined trapezoidal
Discharge capacity, in second-feet	200
Length, in miles	1.5
Side slopes	1.5:1
Bottom width, in feet	6
Depth, in feet	3.2
Fall, in feet per mile	10.6
Pumping Plant	
Pumps	three 4,000 gpm centrifugal pump units one 1,500 gpm centrifugal pump unit
Motors	enclosed, three 125 horsepower and one 75 horsepower
Estimated maximum pumping head, in feet	96
Installed pumping discharge capacity, in second-feet	30
Oro Fino Conduit	
Discharge capacity, in second-feet	30
Canal	1.9 miles, concrete-lined, bottom width of 3.0 feet, depth 1.5 feet, side slopes 1:1
Tunnel	7-foot diameter, 0.5 mile length, concrete-lined horseshoe section

and domestic purposes in Hayfork Valley, as well as for maintenance of summer stream flow in Hayfork Creek.

Layman Reservoir would provide an estimated safe yield of 17,000 acre-feet per season, in addition to providing a firm release of 10 second-feet from May through October for stream flow maintenance in Hayfork Creek below Hayfork Valley. A monthly yield study for the period 1920-21 through 1946-47 indicates that the reservoir would fill and spill each season. A summary of the yield study for Layman Reservoir is presented in Appendix E. The location of the dam is shown on Plate 16, and its principal features are delineated on Plate 24.

Layman Dam would be located in Sections 10 and 15, Township 31 North, Range 11 West, M. D. B. & M. The stream bed elevation at this point is 2,490 feet. Area and capacity data for Layman Reservoir are approximate only and were obtained from a preliminary print of the Geological Survey "Hayfork," quadrangle, at a scale of 1 : 24,000 and a contour interval of 50 feet, and from an enlargement of the "Hoaglin" quadrangle with a contour interval of 100 feet. Computed storage capacities and water surface areas for various pool elevations in the reservoir are presented in Table 74.

Based on a preliminary geologic reconnaissance, the Layman site is suitable for a zoned earthfill dam. Rock at the site is a fine-grained, dense, metamorphic type, well foliated, with numerous quartz seams. Joints in the fresh rock are moderate in number and fairly tight, so that only a nominal amount of medium to light grout would be required.

Stripping requirements under the impervious core have been estimated to be 10 feet of soil plus eight feet of rock on the right abutment, two feet of gravel and three feet of bedrock in the channel section, and approximately six feet of soil and loose rock and eight feet of bedrock on the left abutment. It has been estimated that approximately 75 per cent of the excavated material could be salvaged for use in the pervious section of the dam.

Construction materials for Layman Dam are all available within approximately three miles of the site. Impervious fill material can be obtained from an extensive area of Hayfork Beds, equivalent to the Weaverville formation, which underlies part of Hayfork Valley downstream from the site. The fines of this formation are suitable for core material. This source would provide sufficient impervious material for the dam. Pervious materials, in the form of dredger tailings and stream bed gravels, are available within two miles both upstream and downstream from the site.

Layman Dam, as designed for cost estimating purposes, would be a zoned earthfill structure 160 feet in height from streambed to crest, with a crest length of 780 feet, and a normal pool storage capacity of 21,500 acre-feet. The dam would contain a total volume of fill of 1,209,000 cubic yards. Of this total, 522,000 cubic yards would be contained in the compacted earthfill core.

The spillway would be a side channel type designed for a discharge of 10,000 second-feet under a head of six feet. The overpour section and chute would be cut through the left abutment, and would be concrete lined throughout.

The outlet works would consist of a 36-inch diameter steel pipe, provided with appurtenant valves, placed in a 6-foot diameter concrete-lined horseshoe tunnel through the right abutment. The tunnel would be utilized for stream diversion purposes during the construction period.

The area which would be inundated by Layman Reservoir, with the exception of several cabins and approximately 6 miles of dirt road, is virtually undeveloped. Pertinent data with respect to general features of Layman Dam and Reservoir are presented in Table 75.

The capital cost of Layman Dam and Reservoir was estimated to be about $3,346,000, and corresponding annual costs were estimated to be about $160,000. The cost of development of a firm yield of about 17,000 acre-feet per season would be about $9.50 per

TABLE 74

AREAS AND CAPACITIES OF LAYMAN RESERVOIR

Depth of water at dam, in feet	Water surface elevation, U.S.G.S. datum, in feet	Water surface area, in acres	Storage capacity, in acre-feet
0	2,490	0	0
30	2,520	25	300
70	2,560	90	2,600
110	2,600	225	8,400
150	2,640	506	22,200

TABLE 75

GENERAL FEATURES OF LAYMAN DAM AND RESERVOIR

Dam	
Type	earthfill
Crest elevation, in feet	2,650
Crest length, in feet	780
Crest width, in feet	40
Height, spillway lip above stream bed, in feet	148
Side slopes, upstream	2.5:1
downstream	2.5:1
Freeboard above spillway lip, in feet	12
Elevation of stream bed, in feet	2,490
Volume of fill, in cubic yards	1,209,000
Reservoir	
Surface area at spillway lip, in acres	490
Storage capacity, at spillway lip, in acre-feet	21,500
Drainage area, in square miles	92
Estimated average seasonal runoff, in acre-feet	125,500
Estimated safe seasonal yield, in acre-feet	17,000
Type of spillway	side channel with concrete control section and lined chute over left abutment
Spillway discharge capacity, in second-feet	10,000
Type of outlet	36 inch diameter steel pipe inside 6-foot diameter tunnel through right abutment

acre-foot. A detailed cost estimate is presented in Appendix F.

Morehouse Dam and Reservoir. Morehouse Reservoir would be created by the construction of a dam on the Salmon River approximately one-half mile downstream from the mouth of Morehouse Creek. Water released from the reservoir would be utilized for the generation of hydroelectric power in Morehouse Power Plant, located at the base of the dam.

Based on a reservoir yield study for the period 1921-22 through 1952-53, Morehouse Reservoir would provide an average annual yield of 799,000 acre-feet, which, when passed through Morehouse Power Plant, would generate an average of 365,000,000 kilowatt-hours annually. The power plant would have an installed capacity of 90,000 kilowatts, 80,000 kilowatts of which would be dependable capacity. A summary of the yield study for Morehouse Reservoir is presented in Appendix E. Location of the Morehouse Project is shown on Plate 16, while its principal features are delineated on Plate 24.

Morehouse Dam would be located on the Salmon River in Section 28, Township 11 North, Range 7 East, H. B. & M. The stream bed elevation at this point is 970 feet. Approximate storage capacities and water surface areas for various pool elevations were estimated from the United States Geological Survey "Sawyer's Bar" quadrangle, scale 1 : 125,000, contour interval 100 feet. Results of these estimates are presented in Table 76.

Based on a preliminary geologic reconnaissance report, the Morehouse dam site would be suitable for a concrete gravity, concrete arch, or rockfill dam. The dam site is in a very narrow channel section that has been swept clean of detritus. Bedrock consists of a series of foliated metamorphics which have been intruded in place by igneous dikes and sills. The metamorphics were probably sedimentary in origin, but would now be classed chiefly as quartzose gneisses. Blocky jointing has been moderately developed in these rocks. Shears and faults appear to be of only minor importance. A thin mantle of slide rock occurs on both abutments. The foliation strikes generally across the channel and dips nearly vertically.

TABLE 76

AREAS AND CAPACITIES OF MOREHOUSE RESERVOIR

Depth of water at dam, in feet	Water surface elevation, U.S.G.S. datum, in feet	Water surface area, in acres	Storage capacity, in acre-feet
0	970	0	0
130	1,100	60	20,000
230	1,200	850	72,000
330	1,300	1,740	200,000
430	1,400	2,900	433,000
530	1,500	4,220	790,000
560	1,530	4,690	910,000

As a result of limited quantities of impervious fill material, and the abundance of blocky rock, a rockfill dam with a thin impervious core was designed for the purpose of estimating the cost of a structure at this site. The proposed structure, 575 feet in height, with an upstream outer slope of 2.5 : 1, a downstream outer slope of 1.5 : 1, and a crest width of 40 feet, would contain a total of 16,384,000 cubic yards of embankment. Of this total, 1,160,000 cubic yards would comprise a thin inclined core of select impervious material, and 1,632,000 cubic yards would consist of well-graded filter material placed in inclined upstream and downstream transition zones. The remainder of the fill, 13,592,000 cubic yards, would consist of dumped and sluiced quarried rock. Satisfactory rockfill material, in abundant quantities, is available in the immediate vicinity of the site, while suitable impervious core material is also available in limited, but sufficient, quantities within a three-mile haul distance from the site. Gravel suitable for concrete aggregate is quite limited near the site. Haul distances exceeding six to eight miles would be involved if a major concrete structure were considered for the Morehouse site.

Stripping under the entire fill, for the type of structure considered, would amount to three feet of rock on the right abutment, four feet of rock on the left abutment, and four feet of sand, gravel, and boulders in the channel section. A cutoff under the impervious core would be excavated in rock to depths of 18 feet on the left abutment, 15 feet on the right abutment, and six feet in the channel section. Light to moderate grouting would probably be required in both abutments and in the channel section.

The spillway at the Morehouse site would be constructed to take advantage of natural topography just north of the dam axis on the right bank of the Salmon River. The ridge separating Morehouse Creek and the Salmon River contains a saddle at elevation 1,530, providing an excellent spillway site in good foundation rock. The design flood inflow was estimated to be 65,000 second-feet. A concrete overpour weir 500 feet in length would, under 10 feet of head, discharge a design flood of 55,000 second-feet into the Salmon River immediately downstream from the dam. The discharge chute would be unlined and nonconverging.

The outlet works for Morehouse Dam would consist of a 12-foot diameter welded steel penstock placed inside a 29-foot diameter lined diversion tunnel through the right abutment. The tunnel would be utilized for stream diversion during the construction period.

The area which would be inundated by Morehouse Reservoir is a narrow, V-shaped canyon containing several mines, a county road, the small settlement of Forks of Salmon, and scattered cabins.

Pertinent data with respect to general features of the Morehouse Project, as designed for cost estimating purposes, are presented in Table 77.

The total capital cost of the Morehouse Dam, Reservoir, and Power Plant was estimated to be $54,942,000, and the corresponding annual costs were estimated to be $3,046,000. Annual revenue from the sale of electric energy was estimated to be about $2,800,000. A detailed cost estimate is presented in Appendix F.

Summary of Plans for Local Development

Local water supply developments in the Klamath River Basin are primarily for the purpose of providing irrigation water supplies. Where desirable or practical flood control, municipal water supply, recreation, stream flow maintenance, and hydroelectric power features have been included in the plans.

Reservoirs in the Upper Klamath River Basin would include Beatty and Chiloquin Narrows Reservoirs on the Sprague River. These reservoirs would provide local irrigation supplies and increase the yield of the Upper Basin by nearly 300,000 acre-feet per season. Boundary Reservoir on Lost River would increase the seasonal yield of that stream to 41,000 acre-feet, almost twice the 22,000 acre-feet now developed in Clear Lake Reservoir. Klamath Project Extensions would include a number of new works in the Klamath Project to serve an additional 41,000 acre-feet of water seasonally to 14,000 acres of irrigable land along the fringes of the project area. Plans to serve water to irrigable lands in Butte Valley and the Oklahoma District have been proposed by the United States Bureau of Reclamation. About 100,000 acre-feet per season would be diverted from the Klamath River above Keno and pumped to these areas.

TABLE 77

GENERAL FEATURES OF MOREHOUSE PROJECT

Dam	
Type	rockfill with inclined impervious core
Crest elevation, in feet	1,545
Crest length, in feet	1,700
Crest width, in feet	40
Height, spillway lip above stream bed, in feet	560
Side slopes, upstream	2.5:1
downstream	1.5:1
Freeboard above spillway lip, in feet	15
Stream bed elevation, in feet	970
Volume of fill, in cubic yards	16,384,000
Reservoir	
Surface area at spillway lip, in acres	4,690
Storage capacity at spillway lip, in acre-feet	910,000
Drainage area, in square miles	565
Type of spillway	concrete weir and unlined chute over ridge forming right abutment
Spillway discharge capacity, in second-feet	55,000
Type of outlet	12-foot diameter steel pipe inside 29-foot diameter lined tunnel through right abutment
Estimated average annual yield, in acre-feet	799,000
Power Plant	
Maximum static head, in feet	560
Tailrace elevation, in feet	970
Installed capacity, in kilowatts	90,000
Dependable capacity, in kilowatts	80,000
Number of generating units	3
Firm annual energy output, in kilowatt-hours	238,400,000
Average annual energy output, in kilowatt-hours	365,200,000

In Shasta Valley, works proposed for local development include Montague Dam and Reservoir on Shasta River, and pumping plants to deliver about 84,000 acre-feet of water seasonally to lands in the northern end of the valley. An alternative project on Shasta River, Grenada Ranch Dam and Reservoir, would develop about 20,000 acre-feet of new water seasonally. In addition to supplying required irrigation water, this project would be a desirable source of municipal water supply for towns in Shasta Valley. Table Rock Reservoir would regulate the natural flow of Little Shasta River to provide a firm irrigation supply of about 12,000 acre-feet per season. The Shasta Valley Import Project would include Iron Gate Dam on the Klamath River, and pumping plants and conduits, to divert 122,000 acre-feet of water seasonally from Klamath River into Shasta Valley to meet the additional supplemental water requirements of the area.

In Scott Valley, plans are presented for both ground water and surface water development. Cost estimates indicate that the ground water plan would be the less expensive alternative. The ground water pumping and distribution system, with 64 pumped wells and 160 miles of canal, would deliver about 50,000 acre-feet per season at an average annual cost of approximately $8.00 per acre foot. Possible surface water developments include Highland Dam and Reservoir on Moffet Creek, Callahan Dam and Reservoir on Scott River, Grouse Creek Dam and Reservoir on Scott River, Etna Dam and Reservoir on French Creek, and Mugginsville Dam and Reservoir on Mill Creek. The least costly of these surface developments would be Callahan Dam and Reservoir, which would develop about 78,000 acre-feet of water seasonally at an annual cost of $7.00 per acre foot, not including the cost of conveyance works. The most expensive development would be Mugginsville Dam and Reservoir, with a seasonal yield of 16,000 acre-feet of water at an average annual cost of about $20.00 per acre foot, not including the cost of conveyance works.

Other developments in the Klamath River Basin would include Layman Dam and Reservoir on Hayfork Creek, which would provide about 17,000 acre-feet of water seasonally for an irrigation supply for Hayfork Valley. Morehouse Dam and Reservoir on Salmon River would be principally for the purpose of generating hydroelectric energy. This project would utilize about 799,000 acre-feet of water seasonally, and would generate an average of 343,000,000 kilowatt hours of electric energy.

Data on the general features, capital costs, and annual costs of the local development works for the

Klamath River Basin, are summarized in Table 78. The locations of the works are shown on Plate 16.

THE CALIFORNIA AQUEDUCT SYSTEM

The California Aqueduct System, comprising a system of works extending from near the Oregon line to near the Mexican border, will ultimately transport more than 21,000,000 acre-feet of surplus water each season to areas of inherent deficiency. Of this amount, about 8,000,000 acre-feet will be from the Klamath, Trinity, Mad, Van Duzen, and Smith River Basins, with the remainder from the Eel and Sacramento River Basins. This amount does not include water to be diverted from the Klamath River Basin by the Trinity Division of the Central Valley Project, which is presently scheduled to divert about 800,000 acre-feet per season into the Central Valley. Plate 16 of this report, entitled "Features of The California Water Plan Within the Klamath River Basin," depicts in diagrammatic form the general nature of this system of works. Also shown on this plate are the previously discussed local water resource developments included as features of The California Water Plan.

Works constructed on the South Fork of the Smith, the Klamath, the Trinity, the Van Duzen, and the Mad Rivers would be primarily for conserving surplus waters for export. These works will also produce local benefits from power generation, enhancement of stream flow for fish, wildlife, and recreation, flood control, water quality control, and beneficial consumptive uses of water. The plan would include a series of major regulating reservoirs, most of which would be located contiguously along both the Klamath and Trinity Rivers from the vicinity of their junction upstream. Other reservoirs for conservation and transport of water to the Klamath and Trinity river system would be located on nearby streams.

A number of conduits, pumping plants, and hydroelectric power plants would be appurtenant to the dams and reservoirs. The waters thus conserved would be conveyed by gravity to the Trinity River and pumped through a tunnel under the Trinity Mountains into the Sacramento Valley. A considerable amount of hydroelectric power would be developed in the drop to the floor of the valley. The Klamath-Trinity Division, which is described in some detail in the ensuing paragraphs, comprises the develop-

TABLE 78

SUMMARY OF WORKS FOR LOCAL DEVELOPMENT IN THE KLAMATH RIVER BASIN

Development and dam and reservoir	Stream	Purpose[1]	Reservoir storage capacity, in acre-feet	Safe seasonal yield, in acre-feet	Estimated cost[2]		Cost per acre-foot of safe seasonal yield,[3] in dollars
					Capital, in dollars	Annual, in dollars	
Upper Klamath River Basin							
Boundary	Lost River	I, FC	100,000	41,000	4,000,000	195,000	4.80
Beatty	Sprague River	I	150,000	110,000	4,700,000	233,000	2.10
Chiloquin Narrows	Sprague River	I	440,000	280,000	7,100,000	361,000	2.00
Klamath Project Extensions		I		41,000			
Butte Valley-Oklahoma District	Klamath River	I		100,000	19,000,000		
Shasta Valley							
Montague Project	Shasta River	I, R	87,000	84,000	7,992,000	715,000	8.50
Grenada Ranch Project	Shasta River	I, M	22,800	20,000	2,030,000	120,000	6.00
Table Rock Reservoir	Little Shasta River	I, R	10,000	11,800	2,690,000	130,000	11.00
Shasta Valley Import Project							
Iron Gate Dam and Reservoir	Klamath River	I, R	35,400		3,982,000	182,000	
Pumping Plants and Bogus Conduit				122,000	14,580,000	1,689,000	
Red School Reservoir	Willow Creek	I	1,700		1,402,000	66,000	
Subtotal, Shasta Valley Import Project				122,000	19,964,000	1,937,000	16.00
Scott Valley							
Ground Water Basin Development							
Eastside Service Area		I		21,200	1,583,000	183,000	8.60
Westside Service Area		I		8,700	610,000	70,000	8.00
Valley Service Area		I		3,900	171,000	18,000	4.60
Quartz Valley Service Area		I		15,500	914,000	118,000	7.60
Highland Reservoir	Moffett Creek	I, R	26,000	9,800	4,092,000	195,000	20.00
Callahan Reservoir	Scott River	I, FC, R	133,000	77,500	10,895,000	522,000	6.80
Grouse Creek Reservoir	East Fork Scott River	I, R	50,000	20,000	4,130,000	200,000	10.00
Etna Reservoir	French Creek	I, R	12,000	11,000	2,640,000	125,000	11.50
Mugginsville Reservoir	Mill Creek	I, R	23,000	16,000	6,724,000	323,000	20.00
Other Developments in Klamath River Basin							
Layman Reservoir	Hayfork Creek	I, R	21,500	17,000	3,346,000	160,000	9.50
Morehouse Reservoir	Salmon River	P, R	910,000	799,000	54,942,000	3,046,000	

[1] I = Irrigation; M = Municipal Water Supply; P = Hydroelectric Power; R = Recreation, including stream flow maintenance; FC = Flood control.
[2] Including interest at 3.5 per cent per annum.
[3] Cost per acre-foot of safe seasonal yield does not take into account allocation of costs to non-reimbursable items such as flood control and recreation. All costs include repayment with interest.

ments on or associated with the Klamath River and the Trinity River.

Klamath River Development

Structures included in the Klamath River Development comprise Hamburg, Happy Camp, Slate Creek or a substitute therefor, and Humboldt Dams and Reservoirs on the Klamath River, and their associated power plants; Canthook and Black Hawk Dams and Reservoirs on the South Fork of the Smith River; and Black Hawk and Beaver Pumping Plants. Cantpeak Tunnel, connecting the Smith and Klamath Rivers, as well as Deerhorn Tunnel, connecting the Klamath and Trinity Rivers, are also included as features of this development. Recent geologic exploration at the Slate Creek dam site has unearthed unfavorable foundation conditions which indicate that it may be more economical to select an alternative site.

Runoff of the upper Klamath River would first be regulated in Hamburg Reservoir immediately below the confluence of the Scott and Klamath Rivers. It would be a large reservoir with a net storage capacity of 1,570,000 acre-feet. Releases from Hamburg Reservoir would flow through Hamburg Power Plant and then into Happy Camp Reservoir, formed by Happy Camp Dam located about 3 miles downstream from Happy Camp.

Happy Camp Reservoir, the largest reservoir of the Klamath River Development, would have an active storage capacity of 3,488,000 acre-feet. Releases from the reservoir would flow through Happy Camp Power Plant, thence downstream into the Klamath River for further regulation in Slate Creek Reservoir.

It should be pointed out that an initiative measure approved by the electorate in 1924 prohibits the construction of a dam at any point on the Klamath River below its confluence with the Shasta River. The effect of this statute upon the proposed works of The California Water Plan is not known. However, studies made after the publication of Bulletin No. 3 indicate that these dams on the Klamath River will probably be built only as one of the latter stages of the plan, many years in the future.

Surplus flows of the South Fork of the Smith River could be conserved in Canthook Reservoir, located about 10 miles upstream from the main stem of the river. Black Hawk Dam would also be constructed on the South Fork of the Smith River immediately upstream from Canthook Reservoir. The primary purpose of Black Hawk Reservoir would be to provide direct gravity diversion from the South Fork of the Smith River to Slate Creek Reservoir on the Klamath River through a connecting conduit, Cantpeak Tunnel. Waters would be lifted from Canthook Reservoir into Black Hawk Reservoir by Black Hawk Pumping Plant, located within Black Hawk Dam.

Releases from Hamburg and Happy Camp Reservoirs on the Klamath River, Canthook Reservoir on the South Fork of the Smith River, and surface inflow from drainage areas below Happy Camp Reservoir, would be further regulated in Slate Creek Reservoir, located on the Klamath River about 7 miles above the mouth of the Trinity River. Slate Creek Reservoir would have an active storage capacity of 1,566,000 acre-feet, and would impound and divert reregulated water in the average seasonal amount of 4,700,000 acre-feet for conveyance by means of Deerhorn Tunnel into Beaver Reservoir on the Trinity River.

Unregulated flows of the Klamath River would be controlled by Humboldt Dam, located on the Klamath River just below its confluence with the Trinity River, nearly on the Del Norte-Humboldt county line. Humboldt Reservoir would back water up the river to the downstream toes of both Beaver and Slate Creek Dams. The waters conserved by Humboldt Reservoir, amounting to about 1,205,000 acre-feet per season, would be lifted into Beaver Reservoir by Beaver Pumping Plant, located just below Beaver Dam. Thus, a total of 5,900,000 acre-feet per season would be delivered to Beaver Reservoir from the facilities of the Klamath River Development.

Trinity River Development

The Trinity River Development would involve the construction of Beaver, Burnt Ranch, and Helena Dams on the Trinity River; Eaton Dam on the Van Duzen River; Ranger Station Dam or a substitute therefor, on the Mad River; and Eltapom Dam on the South Fork of the Trinity River. The development would also include the construction of Helena Power Plant on the Trinity River; Sulphur Glade and Eltapom Power Plants on the South Fork of the Trinity River; and Burnt Ranch Pumping Plant on the Trinity River. Three major tunnels, the Sulphur Glade, War Cry, and Big Flat, would be required to convey conserved surplus waters from the proposed reservoirs to the Sacramento River Basin.

Beaver Reservoir would receive water pumped from Humboldt Reservoir, located downstream on the Klamath River, and all water developed in the Klamath River above Humboldt Reservoir and conveyed by means of Deerhorn Tunnel to Beaver Reservoir, as previously described under the Klamath River Development. In addition, Beaver Reservoir would conserve the natural runoff from the Trinity River drainage below Burnt Ranch and Eltapom Reservoirs. Beaver Dam would be located on the Trinity River just below Hoopa Valley, about 6 miles upstream from the confluence of the Trinity and Klamath Rivers.

Burnt Ranch Pumping Plant, located at the upper end of Beaver Reservoir and at the downstream toe of Burnt Ranch Dam, would lift water from Beaver Reservoir to Burnt Ranch Reservoir. Water would be pumped into Burnt Ranch Reservoir on a uniform

TABLE 79

GENERAL FEATURES OF KLAMATH-TRINITY DIVISION, CALIFORNIA AQUEDUCT SYSTEM

(These works show future development possibilities. They are not project proposals.)

Dam and reservoir	Stream	Dam: Location*	Dam: Type	Dam: Height, in feet	Normal pool elevation, in feet	Storage capacity, in acre-feet: Gross	Storage capacity, in acre-feet: Active	Seasonal yield, in acre-feet	Purpose	Place of water use
Klamath River Development										
Hamburg	Klamath River	Sec. 31, T46N, R10W MDB&M	CG	445	1,960	1,850,000	1,570,000	1,136,000	I, U, FC, R, F, P	Klamath River Basin and California Aqueduct service area
Happy Camp	Klamath River	Sec. 33, T16N, R7E	CG	625	1,570	4,120,000	3,490,000	761,000	I, U, FC, R, F, P	
Slate Creek	Klamath River	Sec. 19, T10N, R5E	R	775	1,000	5,480,000	1,570,000	1,985,000	I, U, FC, R, F	
Canthook	Smith River	Sec. 10, T15N, R2E	CG	623	1,095	1,230,000	1,030,000	830,000	I, U, FC, R, F	Smith River Basin and California Aqueduct service area
Black Hawk	Smith River	Sec. 19, T15N, R3E	CG	413	1,123	88,000	48,000	none	Diversion to Cantpeak Tunnel	
Humboldt	Klamath River	Sec. 10, T12N, R2E	CG	410	430	1,940,000	1,330,000	1,205,000	I, U, FC, R, F	Klamath River Basin and California Aqueduct service area
Trinity River Development										
Beaver	Trinity River	Sec. 2, T8N, R4E	CG	730	950	7,760,000	1,600,000	720,000	I, U, FC, R, F	Trinity River Basin and California Aqueduct service area
Burnt Ranch	Trinity River	Sec. 13, T5N, R6E	CA	355	1,220	245,000	36,000	none	Diversion to Big Flat Tunnel	
Helena	Trinity River	Sec. 36, T34N, R12W MDB&M	CG	575	1,852	3,050,000	2,670,000	611,000	I, U, FC, R, F, P	
Eaton	Van Duzen River	Sec. 5, T1N, R5E	E	396	2,700	730,000	500,000			Van Duzen and Mad River Basins and California Aqueduct service area
Ranger Station	Mad River	Sec. 17, T1N, R6E	E	323	2,700	500,000	435,000	398,000	I, U, FC, R, F, P	
Eltapom	South Fork Trinity River	Sec. 3, T3N, R6E	R	420	1,620	1,260,000	680,000	536,000	I, U, FC, R, F, P	Trinity River Basin and California Aqueduct service area
Eltapom	South Fork Trinity River	Sec. 28, T4N, R6E	CG	225	1,264	26,000	6,000	none	Afterbay	
Clear Creek Development										
Kanaka	Clear Creek	Sec. 22, T31N, R6W MDB&M	E	460	1,135	415,000	105,000	none	I, U, FC, R, F, P	Sacramento River Basin and California Aqueduct service area
Saeltzer	Clear Creek	Sec. 31, T31N, R5W MDB&M	E	107	650	32,000	6,000	none	P	Conveyance facility only
TOTALS						28,726,000	15,076,000			

TABLE 79 (Continued)

Power plant	Location*	Average head, in feet	Installed capacity, in kilowatts	Average annual energy generation, in kilowatt-hours
Klamath River Development				
Hamburg	Sec. 31, T46N, R10W, MDB&M	388	66,600	384,400,000
Happy Camp	Sec. 33, T16N, R7E	476	135,400	786,900,000
Trinity River Development				
Helena	Sec. 36, T34N, R12W, MDB&M	468	42,600	248,400,000
Sulphur Glade	Sec. 25, T2N, R6E	1,007	94,000	354,500,000
Eltapom	Sec. 3, T3N, R6E	324	51,800	266,400,000
Clear Creek Development				
Kanaka	Sec. 22, T31N, R6W, MDB&M	473	1,025,000	3,420,000,000
Saeltzer	Sec. 31, T31N, R5W, MDB&M	148	330,000	1,110,000,000
TOTALS			1,745,400	6,570,600,000

Pumping plant	Location*	Average head, in feet	Installed capacity, in kilowatts	Seasonal power consumption, in kilowatt-hours
Klamath River Development				
Black Hawk	Sec. 19, T15N, R3E	81	72,000	98,000,000
Beaver	Sec. 2, T8N, R4E	536	254,000	937,000,000
Trinity River Development				
Burnt Ranch	Sec. 13, T5N, R6E	289	762,000	2,792,000,000
TOTALS			1,088,000	3,827,000,000

Tunnel	Average flow, in second-feet	Length, in miles
Klamath River Development		
Cantpeak	1,147	15.3
Deerhorn	6,500	10.3
Trinity River Development		
Mad	240	0.4
Sulphur Glade	1,375	4.6
War Cry	1,291	9.7
Big Flat	11,300	35.4
TOTAL		75.7

Symbols of type of dam
E—Earthfill
R—Rockfill
CG—Concrete gravity
CA—Concrete arch

Symbols of Purpose
I—Irrigation
U—Urban (domestic, municipal, industrial)
FC—Flood control
R—Recreation
F—Enhancement of fish environment
P—Power generation

* Humboldt Base and Meridian unless otherwise indicated

monthly flow basis, and off-peak electric energy would be utilized in the interest of minimizing power costs.

Waters of the Van Duzen River would be developed by Eaton Dam and Reservoir, located about 2 miles downstream from the community of Dinsmores, about 4 miles west of the Humboldt-Trinity county line. Surplus flows of the Mad River could similarly be developed by a reservoir on that stream between Butler Valley and the Ruth site. The Ranger Station site was first selected as having several advantages due to its strategic location. However, preliminary geological examination indicated conditions which appear somewhat unfavorable to the most economic construction and, in consequence, further study is in process to find a more favorable alternative. It appears that satisfactory alternatives to Ranger Station can be found.

The yield from Eaton Reservoir could be conducted by tunnel to the Mad River, and the yield from the two reservoirs could be conveyed by tunnel into the South Fork of the Trinity River above Eltapom dam site. The most advantageous location would be at the Sulphur Glade tunnel site, which would permit construction of the Sulphur Glade Power Plant to make use of the head differential between the Mad River and the South Fork of the Trinity River.

Eltapom Dam and Reservoir, located on the South Fork of the Trinity River immediately downstream from Hyampom Valley, would regulate runoff of the South Fork of the Trinity River and the releases from Eaton and Ranger Station Reservoirs which, as previously stated, would pass through the Sulphur Glade Power Plant. The total waters thus collected in Eltapom Reservoir would be released through Eltapom Power Plant, located at the base of the dam, and thence diverted through War Cry Tunnel into Burnt Ranch Reservoir on the Trinity River.

Helena Dam and Reservoir, constructed on the Trinity River above Burnt Ranch Reservoir, would conserve the natural flows of the Trinity River and generate hydroelectric energy by releases through Helena Power Plant located at the base of the dam. The reservoir would have a capacity of 3,050,000 acre-feet.

Burnt Ranch Reservoir, formed by Burnt Ranch Dam, located on the Trinity River about 3 miles upstream from the mouth of New River, would be the key reservoir of the Klamath-Trinity Division, as it would serve as a point of convergence for all surplus water delivered from the Klamath, Smith, Trinity, Mad, and Van Duzen Rivers. Although the reservoir would have a gross storage capacity of 246,000 acre-feet, only 36,000 acre-feet would be utilized for active storage, in the interest of maintaining maximum water surface elevation to assure necessary discharge into Big Flat Tunnel. Thus, Burnt Ranch Reservoir would serve primarily as a forebay for Big Flat Tunnel, the principal interbasin export conduit, which would convey water to Clear Creek in the Sacramento Valley. Because of the tremendous quantities of waters involved under ultimate conditions, and the magnitude of the cost of works required to transfer this water from Burnt Ranch Reservoir to Clear Creek, it is proposed that the Big Flat Tunnel be constructed in two parallel stages, or bores, each being 35 miles in length. The first bore would have a capacity of about 3,200 second-feet and the second bore would have a capacity of 8,100 second-feet. Big Flat Tunnel would discharge into Kanaka Reservoir on Clear Creek in the Sacramento Valley.

Trinity and Lewiston Dams and Reservoirs, which will make water available for diversion from the Trinity River to the Sacramento River, are presently under construction by the United States Bureau of Reclamation. This project, known as the Trinity River Division of the Central Valley Project, is a

TABLE 80

SUMMARY OF CAPITAL COSTS OF KLAMATH-TRINITY DIVISION, CALIFORNIA AQUEDUCT SYSTEM

Item	Capital cost*
Klamath Development	
Hamburg Dam and Reservoir	$57,480,000
Hamburg Power Plant	10,030,000
Happy Camp Dam and Reservoir	96,090,000
Happy Camp Power Plant	17,210,000
Slate Creek Dam and Reservoir	151,230,000
Canthook Dam and Reservoir	92,190,000
Black Hawk Dam and Reservoir	49,660,000
Black Hawk Pumping Plant	13,840,000
Cantpeak Tunnel	36,800,000
Humboldt Dam and Reservoir	70,300,000
Relocation of state highway	35,000,000
Deerhorn Tunnel	78,830,000
Beaver Pumping Plant	26,620,000
Subtotal	$735,280,000
Trinity Development	
Beaver Dam and Reservoir	$165,310,000
Burnt Ranch Dam and Reservoir	15,550,000
Burnt Ranch Pumping Plant	73,150,000
Helena Dam and Reservoir	86,260,000
Helena Power Plant	6,510,000
Eaton Dam and Reservoir	15,500,000
Mad Tunnel	650,000
Ranger Station Dam and Reservoir	17,050,000
Sulphur Glade Tunnel	18,690,000
Sulphur Glade Power Plant	16,210,000
Eltapom Dam and Reservoir	41,210,000
Eltapom Power Plant	7,280,000
Eltapom Afterbay	7,630,000
War Cry Tunnel	44,810,000
Big Flat Tunnel	823,440,000
Relocation of state highways	68,000,000
Subtotal	$1,407,250,000
Clear Creek Development	
Kanaka Dam and Reservoir	$21,500,000
Kanaka Power Plant	106,000,000
Saeltzer Dam and Reservoir	2,000,000
Saeltzer Power Plant	43,070,000
Subtotal	$172,570,000
GRAND TOTAL	$2,315,100,000

* At 1955 price levels.

feature of The California Water Plan. The operation of this project would be coordinated with the Klamath-Trinity Division of the California Aqueduct System.

Clear Creek Development

The Clear Creek Development would involve construction of Kanaka and Saeltzer Dams on Clear Creek in the Sacramento River Basin, and an appurtenant power plant at each of the dams. Kanaka Dam and Reservoir, impounding water delivered from Burnt Ranch Reservoir as well as runoff from Clear Creek, would be located on Clear Creek about 8 miles east of Redding.

Water released from Kanaka Reservoir would flow through the Kanaka Power Plant, located near the base of the dam, into Saeltzer Reservoir located immediately downstream. Saeltzer Dam would be situated at the present site of the Saeltzer Diversion Dam, about 6 miles upstream from the confluence of Clear Creek with the Sacramento River. Saeltzer Dam would function primarily for development of the remainder of the power head on Clear Creek below Kanaka Dam, and the final generation of power by facilities of the Klamath-Trinity Division would be accomplished by Saeltzer Power Plant, located at the base of Saeltzer Dam. The water released from Saeltzer Power Plant would flow into Girvan Reservoir, which is a part of the Sacramento Division of the California Aqueduct System.

A summary of the general features of the Klamath-Trinity Division of the California Aqueduct System is shown in Table 79 and a summary of estimated capital costs is shown in Table 80.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The tremendous increase in population in California, since World War II, has brought with it numerous problems, not the least of which is the need for proper development of water resources to serve adequately the growth of water requirements of the State. Increased need for water, due to an expanding population and economy, has been concentrated to a large extent in the southern two-thirds of California. This largely arid, and semiarid region, has been forced to think in terms of importing water from the more humid northern portions of the State to supplement its presently available water supply which is rapidly becoming inadequate. As pressure for such transfer of water has increased, it has become apparent that the water needs in the northern area should first be determined and plans made to satisfy these needs in order to prevent the detrimental effects which would result from indiscriminate and excessive export.

This report has as its basic purpose a broad evaluation of the needs for water in the Klamath River Basin, and a general plan of development that will serve as a guide towards meeting these water needs. It is evident that the estimates of water requirements, and the plans for meeting the requirements must be periodically reviewed and reanalyzed in the light of developing and changing economic conditions.

SUMMARY

The Klamath River Basin is located in northern and northwestern California, and in south-central Oregon, and includes an area of about 10 million acres, the major portion of which is essentially undeveloped at the present time. There are 6,400,000 acres in the California portion and 3,600,000 acres in the Oregon portion of the Basin. The Klamath River is the second largest river in California, exceeded only by the Sacramento River. The Klamath River has a mean seasonal natural flow, at its mouth, of nearly 13,000,000 acre-feet.

There is considerable variation in geological structure, topography, and climate, thoughout the Basin. The wide upper valley area from Shasta Valley north into Oregon is basically volcanic in origin, while the lower portion of the Basin is composed of sedimentary materials. Several high, rugged mountain ranges are located within or bordering the area. Certain sections of these mountain regions have been declared "primitive areas" by the Federal government and are reserved for recreational purposes. On the other hand, many large and relatively flat valleys are suitable for agriculture and stock raising. These valleys lie along the upper rivers and lakes in Oregon and California, and along the tributary Shasta and Scott Rivers. They are located at considerable elevations above sea level. The City of Klamath Falls in Oregon, for example, has an elevation of 4,190 feet and Yreka in California is 2,630 feet above sea level.

The climate is typified by extremes. The mean seasonal precipitation decreases from west to east, with the heaviest concentrations in the coastal mountains and the lightest rainfall on the inland plateau area. In addition, the basin is subject to pronounced wet and dry seasons. Seasonal differences in climate become more noticeable as elevation and distance from the coast increases. In the Upper Basin there is a high percentage of snow, while along the coast precipitation occurs almost entirely as rain. A wide range in temperature is prevalent in the area. The lowest recorded temperature at Klamath, located at the mouth of the Klamath River, is 24 degrees Fahrenheit, and at Klamath Falls the lowest recorded temperature is 24 degrees below zero on the Fahrenheit scale. The growing season covers about 206 days at Klamath, but only 130 days at Tulelake. In general, summers in the interior are hot, dry, and only a few months in length, whereas the winters are long and cold.

About 600,000 acre-feet of water is presently consumed seasonally in the Klamath River Basin. The remaining flow is essentially unused and wastes to the ocean. This flow is considerably in excess of the estimated water requirements necessary for the full development of the resources of the entire basin. Because of the pronounced seasonal wet and dry periods, as well as the variation of precipitation and stream flow from season to season, a system of storage reservoirs would be necessary to conserve and regulate firm water supplies for future local development, as well as for export to water deficient areas of the State.

The economy of the basin is based on agriculture, stock raising, and lumbering. Present indications are that these principal existing industries will continue to be dominant in the future. Mining activity is not as extensive as in the early years, although it still has some significance in the economy and could become more important in the future. The present production of hydroelectric power is only a fraction of the Basin's potential for energy generation.

The present permanent population of the Basin is only about 75,000 people scattered over 15,600 square miles, an average of about 5 to the square mile. However, it is expected that the population will increase two and a half times in the future.

The Klamath River Basin is one of the important recreational regions of California. The recreational aspect of living will become increasingly significant as the population of the State grows. It is, therefore, reasonable to assume that the number of recreational visitors will increase as the population of the State expands. Water, both for direct use of visitors and tourists and for recreational attractions, is an important factor in this development.

The Klamath River is an interstate stream and much of the supplemental water ultimately needed for full development of northern California lands originates in Oregon. On the other hand, one stream, the Lost River, originates in California but is used primarily in Oregon. After it crosses the state line it flows in a wide arc back into Tule Lake in California. Thus both states use water from streams originating in the other state. Development of the agricultural and other resources of the Upper Klamath River Basin in California by use of the waters of the Klamath River will be accomplished by cooperation in the allocation of these waters with the State of Oregon. The economy of each state in this area is dependent upon the other, since they are not separated by natural boundaries.

Both states have recognized this need for cooperative action and, in 1953, each appointed a commission with the primary function of formulating an interstate compact relating to the distribution and use of the waters of the Upper Klamath River Basin. The Klamath River Basin Compact, now in force, is an interstate agreement drawn up by the two commissions to promote the orderly and comprehensive development and use of the water resources of the Klamath River Basin. It has been ratified by the States of California and Oregon and approved by the Congress of the United States. This compact provides for the distribution and use of water within the Upper Klamath River Basin, defined as the drainage area of the Klamath River and all its tributaries upstream from the boundary between Oregon and California, including the closed basins of Butte, Red Rock, Swan Lake, and Lost River Valleys, and Crater Lake.

Terms of the compact establish an order of preference for use of water within the Upper Klamath River Basin, with domestic and municipal use first and irrigation use second, followed in turn by recreational use including requirements for fish and wildlife, industrial use, and use for hydroelectric power generation. Diversions of water outside the Upper Klamath River Basin, with minor exceptions, are prohibited. The compact makes available sufficient water from the Klamath River in Oregon to the California portion of the Upper Basin for the future irrigation of 100,000 acres of land. A permanent commission has been established to administer the terms of the compact.

In 1952, the California Legislature made the first of three annual appropriations for a comprehensive survey of the water resources of the Klamath River Basin. The investigation has been designed to satisfy, as far as practicable, the following major objectives:

1. An inventory of water supplies, both surface and underground, of the Klamath River Basin.
2. A determination of present and ultimate water requirements predicated upon the full development of all natural resources.
3. Determination of areas within the basin now, or ultimately, facing a deficiency in water supply.
4. An estimate of changes in the availability of water supplies caused by bringing under irrigation all lands potentially capable of full development.
5. Preliminary proposals for the development of the water resources of the basin to assure ample supplies for all uses within the basin.

A summary discussion of the studies, results, and accomplishments of the Klamath River Basin investigation reported herein follows.

Water Supply

Water supplies are principally made available to lands in the Klamath River Basin by diversion of surface stream flow. However, some ground water is pumped in portions of the basin. An extensive analysis was made of the precipitation and runoff characteristics of the Klamath River Basin. The water supply studies also included investigation of the opportunity to store and use water in the ground water basins.

The quantity of precipitation ranges from about 100 inches seasonally at Klamath on the coast to 9 inches at Tulelake, and 13 inches at Klamath Falls. Precipitation varies considerably from month to month, but generally exhibits a similarity in distribution throughout the basin in any given season. About 75 per cent of the seasonal precipitation occurs during the 5-month period from November through March.

The highly productive watersheds of the Cascade and Coast Ranges within the Klamath River Basin furnish nearly one-fifth of California's natural runoff. Runoff of the Klamath River at its mouth has ranged from a maximum of about 22,000,000 acre-feet in 1937-38 to a minimum of less than 4,000,000 acre-feet in 1923-24. The maximum instantaneous discharge occurred during the floods of December, 1955, when the recorded flow at the gaging station near the town of Klamath was 425,000 second-feet.

The principal tributary streams of the Klamath River are the Trinity, Salmon, Scott, and Shasta Rivers. The approximate mean seasonal natural flow of each stream as it enters the main stem is 4,560,000 acre-feet, 1,310,000 acre-feet, 580,000 acre-feet and 170,000 acre-feet, respectively. Stream gaging stations on the Klamath River at Keno and at Spencer Bridge, both in Oregon, have recorded flows since 1904, and, for all practical purposes, measure the runoff of the

stream as it enters California. The mean seasonal recorded flow for the 48-year period from 1904-05 through 1951-52 at these stations is 1,150,000 acre-feet.

Both rainfall and snowmelt provide the source of runoff for streams of the Basin. However, variations in topography, vegetative cover, and geologic structure further affect the pattern of runoff. Many of the streams in the Upper Basin are fed by springs, and have relatively uniform seasonal flows. The tributaries near the ocean, on the other hand, are extremely sensitive to the pattern of rainfall.

Ground water basins with adequate storage capacity, and sufficient permeability to justify development for irrigation, exist in Butte and Scott Valleys. Present development of ground water in Butte Valley, in terms of seasonal withdrawals, is estimated to approximate the safe seasonal yield of the basin. In Scott Valley, the virtually undeveloped ground water basin could furnish sufficient water to meet the estimated ultimate requirements of that area. The geologic structure of most of the ground water basins underlying Shasta Valley is such that the resulting storage capacity and permeability is not generally favorable for development. The basin underlying the Pluto's Cave Basalt area, in the vicinity of Big Springs, is apparently suitable for irrigation development.

The main ground water body of the Klamath River Basin in Oregon is continuous, both vertically between formations and horizontally throughout the basin. It generally follows the alluvial valleys, through which the main rivers flow, and continues under Upper and Lower Klamath Lakes. In most instances, this ground water basin does not yield the quantities required for irrigation development, but does provide wells adequate for domestic use.

Both surface and ground water supplies of the Klamath River Basin are generally of excellent mineral quality. Exceptions occur in closed drainage sumps in Shasta Valley, Butte Valley, and Klamath Project areas.

Present and Ultimate Water Requirements

The present and ultimate water requirements of the Klamath River Basin are affected by the physical characteristics of the area and the land use pattern imposed by man. The significant factors considered in estimating the water requirements include:

1. The extent of lands now irrigated and capable of being irrigated in the future, and the characteristics of the irrigable lands with respect to soil types, profile, topography and drainage.
2. The pattern of land use as represented by the existing agricultural economy, and the probable ultimate land use pattern.
3. Consumptive use of water for irrigation, a variable item largely influenced by climate and crop pattern.
4. The efficiency of irrigation water use.
5. Uses of water other than for irrigation, such as for domestic and urban requirements, industry, fish and wildlife maintenance, recreation, and hydroelectric power generation.

Land Use. The area now irrigated in the entire Klamath River Basin has been determined, in field surveys made in 1953, to be about 474,000 acres, of which about 182,000 acres are in California. About 7,500 acres throughout the Basin are utilized for urban and suburban uses, and about 9,000 acres are used for industrial areas and wildlife maintenance areas. Land classification surveys to determine the possible future uses of lands in the Klamath River Basin indicate that a gross area of about 1,070,000 acres could be classed as irrigable.

About 80 per cent of the irrigable area is valley floor land of fair to good quality. The remainder is hill land, generally limited in its crop producing capability by topography and depth of soil. The gross irrigable lands include roads and rights of way, small areas of nonirrigable land, and land out of production for agricultural and economic reasons. It was estimated the gross figure would be reduced to a net area of about 875,000 acres which could be irrigated in any one season. Of the ultimate net irrigated amount, 470,000 acres would be in Oregon and 405,000 acres would be in California. Urban and miscellaneous water service areas are estimated to ultimately total about 28,000 acres in the two states.

The present leading crops in the Klamath River Basin are pasture and hay supporting the dominant livestock industry. The next important crops are, in turn, alfalfa, grain, and potatoes. Based upon trends and the opinions of leading agriculturists in the area, it is estimated that the principal crops in the future will be improved pasture, hay and grain crops, and alfalfa. It is probable that most of the increases in acreage devoted to alfalfa, truck crops, potatoes, and field crops will occur on better quality valley floor lands, and that much of the pasture and hay will be developed on hill lands and valley lands of limited capability.

The estimated increases in the various crop categories are given in Table 81.

Consumptive Use of Applied Water. The consumptive use of applied water on irrigated lands consists of that portion of the applied irrigation water which is used in the processes of plant transpiration and soil evaporation. The remainder of the total seasonal consumptive use is supplied by direct precipitation during the growing season, and by the remainder of precipitation during the nongrowing season which is stored as available moisture in the root zone. Unit values of total consumptive use of water, in feet of depth, were estimated both from field measurements of consumptive use by soil moisture depletion methods,

TABLE 81

SUMMARY OF PRESENT AND ESTIMATED ULTIMATE CROP PATTERNS IN THE KLAMATH RIVER BASIN

Crop	Present irrigated area, in acres	Ultimate irrigated area, in acres	Possible future increase	
			in acres	in per cent
Pasture	245,700	371,400	125,700	51
Hay and grain	140,400	224,900	84,500	60
Alfalfa and clover	61,300	181,600	120,300	197
Truck and potatoes	26,500	64,900	38,400	145
Field crops	100	32,200	32,100	----------
TOTALS	474,000	875,000	401,000	

and by a method of computing unit values of use in relation to climatic factors. The seasonal volume of consumptive use of applied water in any area or unit was computed as the product of the unit value of use, in feet of depth, times the net irrigable area in acres.

The present consumptive use of applied water on irrigated lands in the Klamath River Basin was estimated to be 638,000 acre-feet per season. On urban lands and on miscellaneous water service areas the present consumptive use of applied water was estimated to be about 24,000 acre-feet per season. Present consumptive use of applied water on swamps and marsh lands, and net evaporation from reservoirs, was estimated to be about 540,000 acre-feet per season. The total present consumptive use of applied water was estimated to be about 1,202,000 acre-feet per season. Under ultimate conditions, it was estimated that consumptive use of applied water on irrigated lands would increase to 1,160,000 acre-feet seasonally. The amounts of water required for ultimate consumptive use of applied water for urban, domestic, industrial and miscellaneous uses would be about 60,000 acre-feet per season. Additional ultimate consumptive use of applied water on swamp and marsh lands, and net evaporation from reservoir water surfaces, would be about 730,000 acre-feet per season. The ultimate consumptive use of applied water within the Klamath River Basin would total about 1,950,000 acre-feet per season.

Efficiency of Water Use. The total quantity of water necessary to provide for irrigation and other consumptive use requirements is a function of the efficiency of water use. The amount of water necessary for a farm operation depends upon the method of irrigation, the soil type and slope of the land, reliability of service, and other separately significant items such as cost of the water. The unused water from a farm operation enters natural channels, drainage systems, or adds to the ground water supply. In most contiguous irrigated areas of California, this unused portion of an individual's operation is reused by other farm operations. The result is reflected in a higher water service area efficiency than is the average practice for individual farm operation.

Uses of Water Other than for Irrigation. Uses of water for urban, suburban and domestic purposes are recognized as the highest priority of use. Although these, as well as uses for industrial and recreational purposes, will increase substantially in the future, they are not significant in quantity as compared with the possible irrigation requirement. At present, the population of the Basin is about 75,000, of whom 32,000 live in California. Based on probable future development, it is estimated that the ultimate population in the Basin will be about 200,000. The future population of the California portion of the Basin was estimated at 140,000.

With recommended forest management procedures, the sustained yield of timber lands in the Klamath River Basin is estimated to be about one billion board-feet of logs annually, or about twice the present production. Plywood and fiberboard manufacture has recently become significant, and it is anticipated that paper pulp might be manufactured. Because of the noxious nature of the effluent waste of a pulp mill, it is generally thought that this industry will locate at tidewater unless other economic methods are developed to dispose of the mill waste.

The Upper Klamath River Basin is recognized nationally as an important area both for water fowl hunting and for refuges to protect and maintain water fowl. The refuges will require sufficient water supplies to provide for evaporation in the shallow lakes and marsh areas of Lower Klamath Lake and Clear Lake.

Fisheries, hydroelectric power, and general recreation will become important as time goes on. However, very little additional water will be consumed to satisfy these needs. Flow requirements to meet such needs will generally be developed incidental to other uses of water.

Ultimate Water Requirements. Water requirements for all consumptive purposes within the Klamath River Basin, if provided at strategically located points from which the water could be served to the lands, were estimated to increase seasonally from about 1,600,000 acre-feet under present conditions to about 2,900,000 acre-feet under conditions of ultimate development. The ultimate water requirement within the California portion of the basin would be about 1,500,000 acre-feet per season. Most of this requirement would occur in the Klamath Project area in California, Oklahoma District, Butte Valley, Shasta Valley, and Scott Valley. Ultimate water requirements in the Klamath River Drainage Basin below Scott River, and in the Trinity River Basin, are estimated to be relatively minor.

Areas of Water Deficiency in the Klamath River Basin

At present no area of the Klamath River Basin appears to suffer a serious water deficiency when normal precipitation occurs. However, virtually all the irrigated basins and valleys in the Klamath River Basin within California are now utilizing the available summer stream flow to a reasonably full degree. A subnormal precipitation season results in a shortage of water supply for lands having low priority of right, except within the Klamath Project. In most cases, shortages result from a lack of storage facilities to conserve the winter runoff for late season use. Two areas, Butte Valley and Shasta Valley, have insufficient local water supplies to meet their water requirements under ultimate conditions of development.

The Klamath Project area, which includes the Tulelake Basin and Lower Klamath Lake in California, is the most highly developed agricultural area in the Klamath River Basin. The project is assured of ample water supplies at all times to meet present requirements by the storage capacity provided by Upper Klamath Lake and Clear Lake. Studies made in this investigation indicate that improvements in the storage facilities in and above Upper Klamath Lake, and on the Lost River, could provide water to meet all future water requirements.

Butte Valley is an area where the adequacy of the present water supply to meet present demands is questionable. Consequently, imported water supplies are necessary to meet ultimate requirements. Present water supplies are obtained from unregulated diversions from Butte Creek and pumping from the ground water basin. Assuming that the local water supply is now developed to approximately its safe yield, the ultimate deficiency could amount to as much as 170,000 acre-feet seasonally. Butte Valley is so situated that water could be diverted from the Klamath River in Oregon and pumped into the valley. Plans for such a diversion are discussed in Chapter IV.

In Shasta Valley, the presently developed water supply is normally adequate to meet present demands. Some of the irrigated lands are subject to water deficiencies each season since much of the development comprises diversion of unregulated streams. Surplus water available in Shasta Valley could be conserved in storage reservoirs to enhance present irrigation supplies as well as to irrigate new lands. However, full development of all water in Shasta Valley would not provide sufficient supplies to meet the probable ultimate water requirement of all lands classed as irrigable. It is estimated that after development of local supplies, it would be necessary to import about 200,000 acre-feet from the Klamath River to satisfy all requirements. In addition, about 20,000 acre-feet imported from the Klamath River would be required to meet the ultimate requirements of the Ager Subunit, which is in the northern extension of Shasta Valley.

In Scott Valley present irrigation development is predicated upon diversion of unregulated stream flows. As a result, the water supply is normally adequate, although deficiencies occur on much of the irrigated land during the latter part of the irrigation season. Such deficiencies are greater during seasons of below normal runoff. Regulation of tributary runoff could be provided by conservation reservoirs on several of the main tributaries, or by an extensive system of pumps utilizing the storage capacity of the underlying ground water basin.

Water requirements for the Klamath River Basin below the mouth of Scott River, and for the entire Trinity River watershed, are small in comparison to the available water supply. Any significant water requirements in these areas could be met by development of local water supplies.

Probable Future Change in Flow of the Klamath River

An evaluation of the effect of ultimate development and use upon the quantity of water flowing in the Klamath River was made. This included estimates of the flow of the river under natural conditions; the historical flow of the river; the historical flow as it would have occurred if present (1953) conditions of development had existed throughout the period from 1920 to 1952; and the probable flow of the river, during the period 1920 to 1952, assuming ultimate conditions of development. Such estimates were made for the Klamath River at Keno, and the Klamath River below the Shasta River. Estimates of probable ultimate flow were based on the operation studies of the Klamath River above Keno described in Chapter III.

A summary of the seasonal flow estimates under the foregoing conditions is presented in Table 82, which indicates that there is adequate water in the Klamath River to meet the present and probable ultimate water requirements of the Klamath River Basin in Oregon and in California above the Shasta River. Full development of the basin and maximum utilization of water will reduce the flow of the Klamath River

TABLE 82

AVERAGE SEASONAL FLOWS OF THE KLAMATH RIVER FOR THE PERIOD 1920-21 THROUGH 1951-52

(In acre-feet)

Location	Natural flow	Historical (recorded or adjusted flow)	Historical flow with given condition of development	
			Present	Ultimate
Klamath River at Keno	1,170,000	990,000	870,000	487,000
Klamath River below Shasta River	1,780,000	1,490,000	1,430,000	876,000

below the Shasta River by about 600,000 acre-feet per season. This reduction would have little effect upon the discharge of the Klamath River at its mouth.

Plans for Water Development

The Klamath River Basin Investigation included extensive preliminary studies of possible plans for water development to meet present and ultimate water requirements within the Basin. These plans are included in the California Water Plan as developments to meet local requirements. The portion of the California Aqueduct System within the Klamath River Basin would provide works to export surplus waters from the Klamath and Trinity Rivers. A brief recapitulation of these developments is presented in the following summary.

Upper Klamath River Basin. There is sufficient water in the Upper Klamath River Basin to meet the ultimate needs in both Oregon and California. This, however, is contingent upon the construction of several reservoirs in Oregon to conserve and regulate the available runoff. No increase in the storage capacity of Upper Klamath Lake is proposed. It was determined that two reservoirs on the Sprague River would provide sufficient storage to meet both local demands along the Sprague River and ultimate demands below Upper Klamath Lake.

Beatty Reservoir on the upper reaches of the Sprague River, with a storage capacity of 150,000 acre-feet, would provide a firm seasonal yield of 110,000 acre-feet. The capital cost was estimated to be $4,700,000 and the annual cost would be $233,000.

Chiloquin Narrows Reservoir on the Sprague River near its junction with the Williamson River would have a storage capacity of 440,000 acre-feet and would provide a firm seasonal yield of 280,000 acre-feet. The capital cost of Chiloquin Narrows Reservoir would be $7,100,000 and the annual cost would be $361,000.

Boundary Reservoir, with a storage capacity of 100,000 acre-feet, would be created by a dam on Lost River at the upper end of Langell Valley on the California-Oregon state line. This reservoir would provide a safe seasonal yield of 41,000 acre-feet as compared to a seasonal yield of about 22,000 acre-feet now obtainable from Clear Lake. It would also provide flood control protection to lands in the vicinity of Tulelake and increased water fowl habitat at Clear Lake. The capital cost would be about $4,000,000, and annual cost, including repayment with interest, would be about $195,000.

Additional works comprising the Klamath Project Extensions to serve water to areas bordering the existing Klamath Project have been proposed by the United States Bureau of Reclamation. This agency has also proposed a system of canals and pumping plants, referred to as the Butte Division of the Klamath Project, to serve water from the Klamath River to Butte Valley and the Oklahoma District. The capital cost of the Butte Division was estimated to be about $19,000,000.

Shasta Valley. In this section is presented a summary of possible plans for water supply development prepared during the Klamath River Basin Investigation. This summary does not reflect the changes in plans and costs developed during more detailed studies made in 1958 and 1959 during the Shasta Valley Investigation.

Alternative possibilities for development of additional water on Shasta River are Montague Dam and Reservoir, and Grenada Ranch Dam and Reservoir. Montague Reservoir, with a storage capacity of 87,000 acre-feet, could develop a firm seasonal yield of 84,000 acre-feet. This water would require pumping to make it available to irrigable lands. The capital cost of the Montague Project was estimated to be about $8,000,000 and the corresponding annual cost would be about $715,000. The more recent studies have shown that poor foundation conditions at Montague dam site would cause excessive increases in the cost of a dam at this site. As an alternative, the Gregory Mountain Project has been proposed at a site about four miles upstream. Grenada Ranch Reservoir, with a storage capacity of 22,800 acre-feet, would provide a firm seasonal yield of 20,000 acre-feet, a portion of which would be pumped to serve irrigable lands. This reservoir could also provide water for municipal use in the City of Yreka. The Grenada Ranch Project would have a capital cost of about $2,030,000 and an annual cost of $120,000.

Table Rock Reservoir on Little Shasta River, with a capacity of 10,000 acre-feet, would provide a firm seasonal yield of nearly 12,000 acre-feet. This would enhance irrigation practices in the area served by providing a firm water supply throughout the season. The capital cost of Table Rock Dam and Reservoir was estimated to be $2,700,000 and the corresponding annual cost would be $130,000.

Iron Gate Dam and Reservoir on the Klamath River about 4 miles east of Hornbrook, could be constructed to provide urgently needed regulation of releases from the California-Oregon Power Company's hydroelectric power development on the Klamath River. It would also provide a forebay for pumping irrigation supplies for importation into Shasta Valley. This project, in conjunction with local developments, would supply the ultimate water requirements of Shasta Valley. It would provide for the diversion of 120,000 acre-feet of water per season which would be conveyed to Shasta Valley by the Bogus Conduit. Two pumping lifts would be required along the route. The capital cost of Iron Gate Dam, Bogus Conduit, the two pumping plants, and Red School Reservoir was estimated to be about $20,000,000. The

annual cost, including the cost of electric energy for pumping, would be about $1,937,000.

Scott Valley. The present and ultimate water requirements of Scott Valley could be met by either additional ground water development or regulatory surface storage on several of the tributary streams. A plan for ground water basin development to meet the ultimate water requirements of Scott Valley has been formulated. This would involve a system of 64 wells and pumps, 4 booster pumping plants, and 160 miles of canals and ditches of various capacities. The system would provide a safe seasonal yield of about 50,000 acre-feet to serve supplemental water to lands now irrigated as well as to serve irrigation water to new lands. The capital cost was estimated to be about $3,300,000 and the corresponding annual cost would be about $390,000, including cost of electric energy.

A number of alternative surface storage reservoirs were also considered. These are briefly listed in the following paragraphs.

Highland Dam and Reservoir on Moffett Creek with a storage capacity of 26,000 acre-feet would provide a safe seasonal yield of 9,800 acre-feet to meet supplemental water requirements in Moffett Creek area. The capital cost was estimated to be about $4,100,000 and the annual cost would be $195,000.

Callahan Dam and Reservoir on the Scott River just downstream from the town of Callahan would provide a safe seasonal yield of 77,500 acre-feet if constructed to a storage capacity of 133,000 acre-feet. 15,000 acre-feet of storage space allocated to flood control would provide flood protection to areas downstream. The capital cost was estimated to be about $11,000,000 and the corresponding annual cost would be $522,000.

Grouse Creek Dam and Reservoir on the East Fork of Scott River was considered as an alternative to Callahan Reservoir to avoid flooding the town of Callahan. If constructed to a storage capacity of 50,000 acre-feet Grouse Creek Reservoir would provide a safe seasonal yield of 20,000 acre-feet. It would provide only minor reductions in flood flows. The capital cost was estimated to be $4,100,000 and the annual cost would be about $200,000.

Etna Dam and Reservoir on French Creek about four miles south of Etna would provide new water to lands on the west side of Scott Valley. This reservoir constructed to storage capacity of 12,000 acre-feet would have a safe seasonal yield of 11,000 acre-feet. The capital cost was estimated to be $2,600,000 and the annual cost would be $125,000.

Mugginsville Dam and Reservoir on Mill Creek would impound local runoff as well as surplus water diverted from Shackleford Creek. With a storage capacity of 23,000 acre-feet, this reservoir would have a safe seasonal yield of 16,000 acre-feet. Water would be released by gravity to lands in Quartz Valley, and would be pumped for conveyance to lands in Oro Fino Valley. The capital cost was estimated to be $6,700,000 and the annual cost would be $323,000.

The unit cost of development of new water supplies for Scott Valley from ground water generally appears less than the cost of surface reservoir storage. However, future engineering and economic studies may show a combination of surface and ground water development to be the most desirable.

Developments on Trinity and Salmon Rivers. Layman Dam and Reservoir, located on Hayfork Creek just above its confluence with Carr Creek, would provide an irrigation supply to Hayfork Valley. Releases would be made to maintain summer flows to enhance the fishery in Hayfork Creek. With a storage capacity of 21,500 acre-feet, this reservoir would have a safe seasonal yield of 17,000 acre-feet. The capital cost would be about $3,400,000 and the annual cost would be $160,000.

Morehouse Dam and Reservoir on the Salmon River would be primarily a hydroelectric power development, but would provide regulated releases to downstream units of the California Aqueduct System. With a storage capacity of 910,000 acre-feet, the safe seasonal yield would be nearly 200,000 acre-feet. The power plant would have an installed capacity of 90,000 kilowatts and would generate an average of 365,000,000 kilowatt-hours annually. The capital cost would be about $55,000,000 and the annual cost would be about $3,000,000. Under the criteria used herein the annual cost would exceed the power revenues by a very small margin.

The California Aqueduct System. In addition to incorporating the local developments proposed by the Klamath River Basin Investigation. The California Water Plan includes a number of regulatory reservoirs within and adjacent to the basin. These projects are collectively termed the Klamath-Trinity Division of the California Aqueduct System.

When fully completed, the Klamath-Trinity Division would involve the construction of 15 major dams and reservoirs, with an aggregate active storage capacity of about 15,000,000 acre-feet; 7 hydroelectric power plants with installed power capacity of about 1,700,000 kilowatts; 3 pumping plants with total installed capacity of approximately 1,100,000 kilowatts; and 6 tunnels with a total length of about 76 miles. The works would make available over 9,000,000 acre-feet of water seasonally for export, including the exportable yield, estimated at 872,000 acre-feet, from the Trinity River Division of the Central Valley Project. The hydroelectric power generating facilities of the Klamath-Trinity Division would produce about 6.6 billion kilowatt-hours of electrical energy each year. Of this amount, 3.8 billion kilowatt-hours would be required to pump water to Burnt Ranch Reservoir, from which it would flow through the Big Flat Tun-

nel, beneath the Trinity Divide, into the Sacramento Valley.

The facilities of the Klamath-Trinity Division would be susceptible of progressive staged construction as the need for water and power in California develops. The major reservoirs would accomplish substantial local benefits in the North Coastal Area by providing facilities for control of the very large rain floods characteristic of the area.

CONCLUSIONS

As a result of field surveys and analysis of the data developed for the Klamath River Basin Investigation, the following conclusions have been reached:

1. Water supplies of the Klamath River Basin, if properly developed and utilized, are adequate to satisfy all estimated ultimate water requirements of the Basin.

Providing adequate conservation works are built, the water supply within the Klamath River Basin above the California-Oregon state line will meet the ultimate requirements for municipal, domestic, irrigation, and industrial uses on both Oregon and California lands, including Butte Valley and the Oklahoma District. It will also provide, under ultimate conditions, an average seasonal firm flow of about 200,000 acre-feet in the Klamath River at Keno for hydroelectric power development. However, there would be no excess water within the Klamath River Basin above the state line for export from the Basin.

2. The water supply of Shasta Valley is inadequate to meet local ultimate requirements. It can, however, be augmented by water imported from the Klamath River below the existing hydroelectric power developments. This diversion would be benefited by regulation of water in the Klamath River Basin above the state line.

3. Water supplies originating within the Klamath River Basin below the mouth of the Shasta River are greatly in excess of all foreseeable local demands and will provide a major source of water that can be exported to water-deficient areas throughout California.

4. Both surface and ground water supplies of the Klamath River Basin are generally of excellent mineral quality. Exceptions to this general rule occur in closed drainage sumps in Shasta Valley, Butte Valley, and Klamath Project areas.

5. Ground water basins of sufficient storage capacity and permeability to permit pumping of ground water for irrigation exist in Butte and Scott Valleys. Existing development of ground water pumping in Butte Valley, in terms of seasonal withdrawals, is estimated to approximate the safe yield of the basin. Additional development may cause a draft that would exceed the annual replenishment. In Scott Valley, the virtually undeveloped ground water basin would furnish sufficient water to meet the ultimate requirements of the valley.

The ground water basin underlying Shasta Valley is of such a complex structure, with many variations in storage capacity and permeability, that the only portion deemed suitable for extensive irrigation development is the Pluto's Cave Basalt area in the vicinity of Big Springs. However, wells adequate for irrigation can be developed in other places in Shasta Valley.

6. The present (1953) area of land irrigated each season in the Basin is about 474,000 acres, of which 182,000 acres are in California. Urban and miscellaneous lands occupy about 7,500 acres and 8,900 acres, respectively, with the area in each classification being about equally divided between the two states. The mountainous areas and undeveloped valley lands are used quite extensively for livestock range, timber production, mining, recreation, support of fish and wildlife, and for the natural storage of rainfall and snowmelt.

7. Land classification surveys indicate that about 875,000 acres could ultimately be irrigated. Of this amount, about 470,000 acres would be in Oregon and 405,000 acres would be in California. Urban and miscellaneous water service areas could ultimately total about 28,000 acres in the two states. The agricultural development is predicted to follow its present pattern with large acreages used for pasture and forage corps. Increased livestock raising is also anticipated. With proper forest management, the sustained yield of timber lands in the Klamath River Basin could be brought up to about one billion board feet of logs annually, or about twice the present production.

8. About 75,000 people presently reside in the Klamath River Basin, including about 32,000 people in the California portion. Based on estimates of the agricultural and industrial potential 200,000 people will ultimately reside in the basin, and of this amount 140,000 will be located in California. In addition, the area would be extensively utilized for recreational purposes by a large number of tourists and sportsmen.

9. The present consumptive use of applied water within the Klamath River Basin resulting from irrigation of agricultural lands, use of water on urban and domestic areas, and use of water for industrial and recreational purposes averages about 662,000 acre-feet seasonally. Under probable ultimate conditions of development, the consumptive use of applied water for the foregoing employments would increase to an average of about 1,220,000 acre-feet seasonally. Of this total amount, about 590,000 acre-feet per season would be used within the California portion of the basin. Additional consumptive use of applied water on swamp and marsh lands and on reservoir water surfaces would increase from the present 540,000 acre-feet per season to about 730,000 acre-feet per season. The total ultimate consumptive use of applied water within the Klamath River Basin for all purposes would thus be about 1,950,000 acre-feet per season.

10. Mean seasonal water requirements for all beneficial purposes within the Klamath River Basin will probably increase from about 1,600,000 acre-feet under present conditions to about 2,900,000 acre-feet under conditions of ultimate development. The ultimate mean seasonal water requirement within the California portion of the Basin would be about 1,500,000 acre-feet.

11. The natural runoff of the Klamath River at Keno would have averaged about 1,170,000 acre-feet per season for the period 1920-21 through 1951-52. The average seasonal recorded flow for this period is 990,000 acre-feet. Water supply and consumptive use studies show that had the present (1953) level of water use existed throughout the above period, the average seasonal impaired flow would have been about 870,000 acre-feet.

Based upon a plan of development for supplying the ultimate water requirements, the probable ultimate impaired flow of the Klamath River at Keno would be about 487,000 acre-feet. The seasonal impaired flow of the Klamath River below the mouth of the Shasta River, estimated to be about 1,430,000 acre-feet under present (1953) conditions, would decrease to about 876,000 acre-feet under ultimate conditions.

12. About one-half million acre-feet of additional reservoir storage capacity must be constructed in the Upper Klamath River Basin to provide sufficient yield to meet the ultimate requirements. Plans shown herein for Beatty and Chiloquin Narrows Reservoirs on Sprague River, as well as Boundary Reservoir on Lost River, would provide the required storage. A possible alternative to the Chiloquin Narrows Reservoir would be to increase the usable storage capacity of Upper Klamath Lake.

13. The flow of the Klamath River below the Shasta River, and the flow of the Trinity River system, will be significantly affected by the proposed works and operation of The California Water Plan. Under this development, the entire channel of the Klamath River would be contained within reservoirs, from the mouth of the Shasta River as far downstream as the proposed Humboldt Dam, about 8 miles upstream from the town of Klamath. Also, the Trinity River channel would be inundated by a series of reservoirs from its mouth upstream to Trinity Reservoir, now being constructed. About 9,000,000 acre-feet of water per season would be diverted into the Sacramento River Basin by the works of the California Aqueduct System and the Trinity Division of the Central Valley Project.

14. In years of normal or above normal precipitation and runoff, most irrigated lands have an adequate supply of water. In years of below normal water supply, much of the land in Butte, Shasta and Scott Valleys and in smaller areas throughout the Basin, is subject to severe summer and fall water shortages and reduced productivity. Lands with low priority water rights are operated in such a manner that a water shortage on these lands does not cause severe loss of production. Present supplemental water requirements were not determined.

15. The ultimate mean seasonal supplemental water requirements for the Oklahoma District and Butte Valley would be nearly 170,000 acre-feet. Very little of this could be supplied by additional development of the local water supply. The United States Bureau of Reclamation's proposed plan to divert about 100,000 acre-feet seasonally from the Klamath River into the Oklahoma District and Butte Valley would serve water to most of the better quality lands in the service area. Preliminary studies by the Bureau of Reclamation indicate that the plan would be economically feasible.

16. The ultimate supplemental water requirements of Shasta Valley would be about 270,000 acre-feet per season. The local water supply is not sufficient to meet this demand. Further development of the local water supply, although complicated by lack of reservoir sites above the areas of irrigable land, could supply a portion of the ultimate requirement. Opportunity to develop this additional water exists with the Montague, Grenada Ranch and Table Rock Projects. The first two projects would require pumping to convey the water to irrigable lands. Full utilization of Montague Project would be dependent upon importation of water from the Klamath River for irrigation in the area lying above Montague Reservoir. It should also be noted that development of Grenada Ranch and Table Rock Projects would reduce the yield of the Montague Project. Without regard to possible allocation of portions of the costs to nonreimburseable purposes, the annual cost of water would be about \$8.50 per acre-foot for the Montague Project; \$6.00 per acre-foot for the Grenada Ranch Project; and \$11.00 per acre-foot for the Table Rock Project. These costs do not include additional design requirements found necessary following detailed geologic studies made in 1958.

Supplemental water requirements for Shasta Valley could eventually be met by pumping from the Klamath River. Indications are that the cost for power and construction of facilities for importing 120,000 acre-feet per season would be about \$16.00 per acre-foot. This cost is greatly in excess of prices now paid for irrigation water.

17. The ultimate supplemental water requirements in Scott Valley would be about 72,000 acre-feet seasonally. There is adequate surface runoff and suitable storage sites so that the needs of Scott Valley could be satisfied. Furthermore, this valley is underlain by a ground water basin with sufficient storage capacity and permeability to permit extensive ground water development. From a preliminary investigation, it was concluded that ground water development

would cost less than surface water development. The cost of development of ground water would vary from about $3.00 to $11.00 per acre-foot with an average cost of about $8.00 per acre-foot for 53,000 acre-feet per season. This would include costs of main distribution canals. The cost of water developed in surface reservoirs would vary from about $7.00 to $20.00 per acre-foot, not including distribution canals.

18. The ultimate supplemental water requirements in hydrographic units on the Klamath River downstream from Scott River and in Trinity River hydrographic units are small in quantity and scattered in location. Layman Dam and Reservoir on Hayfork Creek was included in the plans for development to provide a yield of 17,000 acre-feet per season to lands in Hayfork Valley. The cost of development of this project would be about $9.50 per acre-foot. Morehouse Dam and Reservoir on the Salmon River was included as a hydroelectric power project. However, under the criteria used herein, the cost of development would exceed estimated power revenues by a small margin.

RECOMMENDATIONS

It is recommended:

(1) That estimates of ultimate land use and water requirements be reviewed periodically as new data relevant to the relationships of soils, water, and plants is collected and analyzed.

(2) That, in accordance with the policies under which The California Water Plan was formulated, continuing consideration be given to the development of water supplies to meet the needs of upstream areas of the Klamath River Basin in California in conjunction with any plans for exporting water from the Klamath River Basin. Particular consideration should be given as follows:

(a) in the event that development of water supplies for Butte Valley and the Oklahoma District, tentatively planned by the United States Bureau of Reclamation as the Butte Division of the Klamath Project, is shown to be economically justified and financially feasible, all steps within State jurisdiction be taken to aid in the construction of this project.

(b) the results of further and additional studies of economic justification of water conservation projects in Shasta Valley, now in progress and scheduled to be completed in 1960, be used as a guide to future water development in that valley.

(c) in the event that a need for local water development is demonstrated by local interests in Scott Valley, additional engineering study be made of surface and ground water projects to determine their economic and financial feasibility.

(3) That stream gaging stations established during the field investigation, and new installations as required, be maintained on those streams for which future construction of water conservation works is probable, in order to permit more reliable determination of yields of future projects.

(4) That the features of The California Water Plan for local development within the Klamath River Basin, as published in Bulletin No. 3, "The California Water Plan", May, 1957, be modified to include additional plans presented herein.

APPENDIX A

GEOLOGY OF THE KLAMATH RIVER BASIN

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APPENDIX A

GEOLOGY OF THE KLAMATH RIVER BASIN

The Klamath River Basin includes parts of three of the principal geomorphic provinces of the western United States. Geomorphic provinces are areas characterized by like earth forms and usually by similar geologic features. The three provinces represented within the Klamath River Basin are, from east to west, the Modoc-Oregon Lava Plateau, the Cascade Range, and the Klamath Mountains. The Modoc-Oregon Lava Plateau includes nearly all of the Klamath River Basin in California east of, and including, Butte Valley. The Cascade Range forms a north-south belt through the Basin, extending from beyond Crater Lake on the north to Mount Shasta on the south. It is bounded in part on the east by the western edge of Butte Valley and on the west by the edge of Shasta Valley. The Klamath Mountains province includes the entire remainder of the Basin lying west of the Cascade Range.

The geological characteristics of Scott, Shasta, and Butte Valleys in California and the Klamath River Basin in Oregon were delineated and defined by the Ground Water Branch of the United States Geological Survey. This discussion is based on data furnished by the United States Geological Survey as a result of these investigations. "Open file" reports on the investigations have been prepared by the Geological Survey, and the report on Scott Valley has been published in 1958 as Water Supply Paper 1462. Geologic maps and cross sections of the three valleys investigated in California, prepared by the Geological Survey, are included in this report for ready reference.

MODOC-OREGON LAVA PLATEAU

The Sprague River and Lost River hydrographic units, and parts of the Williamson River, Upper Klamath Lake, and Butte Valley units, are located in the Modoc-Oregon Lava Plateau geomorphic province. The Modoc-Oregon Lava Plateau is characterized by broad valleys, frequently containing marshy ground and, in many cases, shallow lakes. The surface drainage system is poorly integrated, most of the water draining finally into the Klamath River.

The consolidated rocks of the Modoc-Oregon Lava Plateau are nearly all of volcanic and volcanic-sedimentary types. The principal formation occurring at and near the ground surface in Oregon is the one known as "volcanic rocks of the High Cascades," consisting of a thick group of lavas containing some sediments, and probably Pliocene to Pleistocene in age. These rocks principally occur as a basaltic lava rock which includes some tuff and sediments, and as a subordinate andesitic unit which apparently does not contain sediments. The andesitic unit occurs north of the latitude of Crater Lake, whereas the basaltic unit, covered in places by unconsolidated Quaternary sediments, underlies almost the entire remainder of the drainage basin south and east of the volcanics surrounding Crater Lake.

The basaltic unit can generally be subdivided into three members, the upper lava rocks, composed of a high percentage of fractured flow breccia; a central volcanic-sedimentary unit containing lapilli tuff, water-laid ash, sandstone, siltstone, and diatomite for which the designation "Yonna formation" has been proposed; and the lower lava rocks, composed of flows which are somewhat more dense and less permeable than the upper lava rocks. Quaternary lava flows, cinder cones, and pyroclastic deposits occur in a number of places in Oregon, the most extensive being the fields of airborne and flow pumice erupted by ancient Mount Mazama, now occupied by Crater Lake. Quaternary alluvial deposits, consisting largely of fine-grained clastic material, peat, volcanic ash, and reworked pumice, occupy some of the valley plains.

A great number of normal faults, in which the most common trend is about 30 degrees west of north, cross the lava plateau in Oregon. This block faulting probably occurred during the middle and late Pleistocene period. Fracture zones along which ground water is free to move occur along the faults, and hydraulic continuity is thus provided between upper and lower aquifers.

Butte Valley in California is part of the Modoc-Oregon Lava Plateau, although the highlands to the west and south belong to the Cascade Province. The region contains three principal valleys, Butte and Red Rock Valleys and Oklahoma Flat, known locally as the Oklahoma District. Butte Valley proper is separated from the Oklahoma District and the Lower Klamath Lake marshland by Mahogany Mountain Ridge, a prominent northwest-trending fault block. The principal cones of the Cascades in this area lie to the west and south of Butte Valley.

The oldest rocks of the Butte Valley region are volcanics of the Western Cascade series, which are exposed where the Klamath River canyon cuts through the Cascades. This series is unconformably overlain by the High Cascades volcanics, which consist chiefly of basalts and basaltic andesites. The High Cascade and later volcanics form the bedrock in most of the Butte Valley region. East of the Cascade

Range proper, volcanic rocks of similar lithologic character underlie most of Mahogany Mountain Ridge, where they make up several large dome-shaped lava cones.

Massive diatomite deposits of Pliocene age are exposed over a large area east of Mahogany Mountain ridge. Volcanic and sedimentary rock units of the Pleistocene include (from oldest to youngest) basaltic flows near lower Klamath Lake, basalt near Sheep Mountain, moraine and fluvioglacial deposits, terrace deposits, lake deposits, Butte Valley basalt, and pyroclastic deposits. The lake deposits underlie a large part of Butte Valley. Butte Valley basalt occurs in the southeastern part of the valley and in the highland area farther to the southeast. Late Pleistocene and recent volcanic rocks and sedimentary deposits include lava flows and cinder cones in the Cascade Range, extensive basaltic extrusions southeast of Sharp Mountain, alluvium, talus debris, and sand dunes.

Normal block faulting is the dominant structural feature of the Butte Valley region east of the Cascades. Vertical displacements vary up to perhaps several thousand feet with minor horizontal movement. The faults follow two principal trends, north and approximately northwest. Butte Valley is a complex down-faulted basin, deepest along its western side. It is separated from the Oklahoma District and the Lower Klamath Lake area, which compose another complex down-faulted basin, by the northwest-trending Mahogany Mountain horst.

CASCADE RANGE

Parts of the Williamson River, Upper Klamath Lake, Butte Valley, Shasta Valley, and Klamath River hydrographic units are characterized by very rugged topography, by chains of volcanic cones, and by a wide variety of volcanic rock types. The rugged Cascade Range includes Mount Shasta, elevation 14,161 feet, one of the highest peaks in the United States.

Crater Lake, which lies just to the north of the Klamath River Basin, fills the collapsed caldera of ancient Mount Mazama. This volcano once achieved a stature of almost 12,000 feet above sea level before the climactic eruptions which sealed its doom. During or immediately following these last-stage eruptions, the entire top of the mountain collapsed, leaving a tremendous pit or caldera between five and six miles across and 4,000 feet deep. The lake itself is nearly 2,000 feet deep. It has no surface outlet.

Such violent volcanic activity has apparently been a common thing in the Cascade Range throughout a considerable period of geologic time. Presently exposed rocks are essentially limited to the Tertiary and Quaternary periods and indicate that most of the volcanism of the range has ocurred within the span of time thus represented. Many of the flows and pyroclastic materials show evidences of having spewed forth from the interior of the earth within the brief span of the last few thousand years.

The Cascade Range contains shield cones, cinder cones, and composite cones. The shield cones are formed by up-welling lava flows and are generally broad with gentle slopes. The cinder cones, formed by the explosive ejection of fragmental lava, may rise from broad, plainlike terrain, or they may form conical protuberances on pre-existing volcanic mountains. Many volcanoes are a composite of the two types of cones.

The two principal volcanic units of the Cascades are the Western Cascades and the High Cascade series. The volcanics of the Western Cascades consist of lava flows and interbedded pyroclastics, in places somewhat altered, of Eocene to Miocene age. Their dip is generally eastward throughout the Cascade Province in the Klamath River Basin. Cascade volcanics include the younger Pliocene and Pleistocene rocks of the Cascades proper, plus the lavas underlying the Modoc-Oregon Lava Plateau. Recent volcanics are present in many places.

Shasta Valley lies along the western side of the Cascade Province in California, and is flanked on the west by rocks of the Klamath Mountains Province. Near Yreka, at the western margin of the valley, marine Upper Cretaceous sandstones and conglomerates unconformably overlie the older Mesozoic and pre-Mesozoic rocks. The Cretaceous rocks are in turn overlain disconformably by the Eocene Umpqua formation, which consists mainly of shales. Some recent geologic studies indicate that Eocene rocks do not exist in this area, but that the formation here called Umpqua is actually Cretaceous in age.

Volcanics of the Western Cascades underlie much of the floor of Shasta Valley, and High Cascade volcanics bound the valley on the east. Mount Shasta itself, on the southeast, was built up mainly during the Pleistocene epoch.

Volcanic rocks make up much of the floor of Shasta Valley from Montague south to Edgewood· The southeastern part of the valley, flatter than most of the remainder, is occupied by the Pluto's Cave basalt, a vast flow of lava erupted from the northeast flank of Mount Shasta within the last few thousand years. The western half of the valley is largely occupied by volcanic rocks of the western Cascade series which have been eroded into hillocks that range from a few feet to 800 feet in height. Morainal and outwash deposits at the south end of the valley were formed during Pleistocene time by glaciers that descended the northwest flanks of Mount Shasta. Over much of the northern part of the valley, older alluvium covers the Cretaceous and Eocene rocks. Younger alluvium underlies the present stream channels and gently sloping fans built by streams issuing from the western mountains, the broad alluvial flats of Little Shasta

Valley, and the considerable portion of western Shasta Valley which is drained by Parks and Willow Creeks and Shasta River.

Portions of the eastern and western margins of Shasta Valley are marked by narrow northwesterly-trending fault blocks. The Snowden horst occurs at the northern end of the valley where it is traceable for about five miles. The Yellow Butte horst bounds the valley on the east in the Big Springs area and is traceable for about eight miles. It is by far the more important of the two horsts. The throw of the western fault of this horst is estimated conservatively to be on the order of 2,000 feet.

KLAMATH MOUNTAINS

Between the Cascade Range and the Pacific Ocean, the Klamath Mountains form a complex rugged range whose peaks and ridges reach some 6,000 to 8,000 feet above sea level. Hydrographic units within the Klamath Mountains geomorphic province include the South Fork of Trinity River, Lower Trinity River, Upper Trinity River, Salmon River, and Scott Valley units, and parts of the Klamath River and Shasta Valley units.

The Klamath Mountains have been developed principally by stream erosion of an uplifted plateau. The mountain mass is transected by the Klamath River which, with its tributaries, often shows a succession of benches on the walls of the canyons. These benches are indicative of repeated rejuvenation of the whole region. Many of them were left covered with terrace gravels, some of which have proven to be auriferous as the streams cut deeper into the surrounding terrain.

The Klamath Mountains Province is in a regional stage of early maturity, and the streams lie in deep, narrow-bottomed canyons. Only in a few places have flats developed in valley bottoms, these usually being either in areas of intersecting streams or where weaker rock zones occur. Scott Valley is considered to be the only basin of major importance in this province susceptible of ground water development. The remainder of the few flat areas are small and contain only shallow, gravelly fill materials.

The wide variation in the nature and occurrence of the rocks of the Klamath Mountains is marked. The rocks range in age from pre-Silurian to Recent, covering an estimated span of more than 400,000,000 years. These rocks include Cretaceous and Eocene sediments on the east; Paleozoic and pre-Silurian meta-sediments and meta-volcanics on the east and towards the center of the province surrounding a batholithic core; and Franciscan (Jurassic) and later sediments on the west. The granitic intrusive grades outwards from its center through areas of acidic (silicic) and basic rock to encompassing fringes of ultra-basic rock (peridotite, etc.). These are in turn bounded by the older metamorphics which were altered and folded during the Jurassic mountain-building upheaval.

Faulting is only moderately important in the Klamath Mountains. Although relatively little is known of the detailed location or significance of individual faults, a series of important northwest-trending faults do occur near the west edge of the province near the northern end of the Coast Ranges.

The bedrock in the Scott Valley area consists of schist, greenstone, consolidated sedimentary rocks, and intrusive rocks ranging from granodiorite to peridotite (the latter now largely altered to serpentine). The oldest rocks are the Salmon and Abrams schists, a series of completely recrystallized sedimentary and volcanic rocks of pre-Silurian age. Unconformably overlying these rocks along the eastern part of Scott Valley are the Chanchelulla beds, consisting of more than 5,000 feet of sandstone, chert, slate, and limestone of Silurian age. Along the northern part of the area, the Salmon and Abrams schists are unconformably overlain by andesitic and basaltic volcanics which have been altered to greenstone and greenstone schist. These altered volcanics may be correlative with either the Copley meta-andesite of pre-Middle Devonian age or the Applegate formation of Upper Triassic age. Intrusive rocks of late Mesozoic age range from peridotite, now largely altered to serpentine, to granodiorite. The granodiorite is the youngest of all the consolidated rocks in the area.

The alluvial fill of Scott Valley consists of Recent alluvium and a few isolated patches of Pleistocene alluvium found along the valley margins. The Recent alluvium, which may reach a maximum thickness of more than 400 feet in the wide central part of the valley between Etna and Greenview, is the only formation tapped by wells in Scott Valley.

A northwest-trending normal fault extends along the mountain front on the west side of Scott Valley. The west side of this fault is upthrown, and the total amount of movement involved is many thousand feet. This fault is cut off north of Shackleford Creek by an east-west trending cross fault, and prominent cross faults are also encountered immediately to the south of Quartz Hill and in the hill northwest of Fort Jones. All these cross faults are upthrown to the north. A high angle reverse fault extends in a northeast-southwest direction through the Chanchelulla beds near the south end of Scott Valley. The south side of this fault is upthrown, probably on the order of several hundred feet.

APPENDIX B

SOIL MOISTURE DEPLETION STUDIES

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APPENDIX B

SOIL MOISTURE DEPLETION STUDIES

Soil moisture depletion studies were conducted as a phase of the Klamath River Basin Investigation to provide additional data to permit the more accurate evaluation of consumptive use of water in the northern mountainous agricultural areas of California. These studies would also provide a basis for using consumptive use data gathered elsewhere in California. As a result, coefficients of consumptive use were developed for applying the Blaney-Criddle method of computing consumptive use of water for irrigated crops.

The method of determining consumptive use of water from soil moisture depletion involves the regular collection of soil samples from representative agricultural and native vegetation plots, determination of both the sampled and oven-dry weight of the soil, reduction of resultant values of contained moisture to equivalent inches depth of water, and, finally, the determination of unit values of consumptive use of water during the intervals between successive samplings. In this discussion the following terms are used as defined:

Consumptive use of water—This refers to water consumed by vegetative growth in transpiration and building of plant tissue, and to water evaporated from adjacent soil, from water surfaces, and from foliage. It also refers to water consumed and evaporated by urban and nonvegetative types of land use.

Applied water—The water delivered to a farmer's headgate in the case of irrigation use, or to an individual's meter in the case of urban use, or its equivalent. It does not include direct precipitation.

Soil sampling—The extraction of soil cores in the field, in six inch or 12 inch length by means of a soil tube or soil auger.

Soil moisture—Water contained in pore spaces of the soil mass between the soil particles. It is expressed either as a percentage of the oven-dry weight of the soil or as equivalent inches of depth of water.

Field capacity—The water content of the soil when downward gravitational movement of water ceases following an irrigation or precipitation, expressed as a percentage of the oven-dry weight of the soil.

Moisture equivalent—An arbitrary measure of the water-holding capacity of soil defined as the amount of water retained by a saturated soil after one thousand revolutions on a centrifuge, expressed as a percentage of the oven-dry weight of the soil. In medium-textured soils, the moisture equivalent is a fairly accurate measure of the field capacity.

Permanent wilting point—The water content of the soil below which plants cannot readily obtain water necessary for their growth, expressed as a percentage of the oven-dry weight of the soil. The response of all crops to the permanent wilting percentage of a given soil is approximately the same with some exceptions. Prunes, for example, in fine-textured soils, have difficulty in obtaining moisture considerably before the soil moisture content reaches the permanent wilting percentage.

Apparent specific gravity—The ratio of the oven-dry weight of a given volume of undisturbed soil to the weight of an equal volume of water.

Equivalent inches depth of water—An expression of the moisture content in inches depth of water of a given stratum of soil, computed by multiplying the depth of soil in inches by the apparent specific gravity, and by the soil moisture expressed in percent, and dividing by 100.

Numerous theoretical and practical problems arise in connection with the soil moisture sampling method. Theoretically, the existence or non-existence of deep percolation after the soil moisture content has reached field capacity is still undetermined. Likewise, the effectiveness of capillary forces in the upward movement of soil moisture has not been definitely delimited. The ability of some plants, particularly native vegetation, to extract moisture when the soil moisture content is below the so-called permanent wilting percentage is also a controversial point. Finally, whether the only factor affecting consumptive use is the species itself, or whether such factors as soil texture, tillage practices, soil fertility, and total amount of water applied affect consumptive use is similarly an undecided question.

By means of the soil moisture depletion method, unit values of consumptive use of water by crops and native vegetation are determined by measuring the changes in soil moisture content by soil sampling, as water is added by irrigation or precipitation and extracted by evaporation and plant transpiration. It has been found experimentally that soils have a usable moisture-holding capacity between the limits of field capacity and the permanent wilting point. A condition

approximating field capacity generally occurs two or three days following a rain or an irrigation when significant gravitational movement of water in the soil ceases. Therefore, it is assumed that loss of soil moisture determined by soil sampling while the moisture content is below field capacity may be attributed to plant transpiration and soil evaporation.

Soil moisture sampling was carried on in the Klamath River Basin through two complete growing seasons from the spring of 1953 to the spring of 1955. Twenty-one plots on irrigated land and fifteen plots of nonirrigated and native lands were selected in Scott, Shasta, and Butte Valleys. The location and description of these plots are shown in Tables B-1 and B-2. Each irrigated plot was a definite area within the field, chosen as representative of the average soil type, crop, and agricultural and irrigation practices. These plots were not fenced or otherwise disturbed to interfere with normal cultivation, irrigation, or harvesting, Care was taken to select plots that had a full seasonal water supply, adequate drainage, and no high water table conditions. Field sampling was carried on actively during the growing season from about the first of April until the latter part of October. Table B-3 shows the observed consumptive use on the irrigated plots.

Native vegetation and non-irrigated crops were investigated during the course of this study primarily to add to the general store of data available on consumptive use of water. Non-irrigated and native vegetation plots were selected to be representative of the area with locations on deep, well-drained soil, free from high water table conditions. Field sampling was conducted on these plots from about March 1 through October at convenient intervals of two or three weeks and immediately after each rainfall during the period. The observed consumptive use of water on non-irrigated and native vegetation plots is shown in Table B-4.

As an example of the procedure followed in the soil sampling program to determine unit values of consumptive use, data from Plot 30, alfalfa irrigated by sprinkler in the Gazelle area of Shasta Valley, are utilized. The location and soil description of this plot are presented in Table B-1, the observed consumptive use is presented in Table B-3.

Soil samples were taken from Plot 30 one to two days following each irrigation, whenever possible between irrigations, and immediately prior to the next irrigation. Sampling at such times was done in order to obtain the soil moisture content at or near field capacity after irrigation, and at the minimum point to which it was reduced by evaporation and plant transpiration prior to the next irrigation.

The soil samples were obtained with the improved Veihmeyer soil tube, consisting of a nickel-steel tube, a detachable cutting point, and a driving head. The tube is forced into the soil by blows from a 15-pound drop hammer, and is removed by hand or by a specially designed jack. It extracts a core of soil approximately $\frac{1}{8}$-inch in diameter. At the time of each sampling, cores were taken at one-foot intervals from at least three randomly selected locations on the plot. Total depth of sampling at Plot 30 was six feet, the effective root depth. On all plots, cores were taken either to or below the lower limit of the effective root depth.

The soil samples were placed in covered cans upon removal from the soil tube, and were taken to the laboratory to be weighed and dried. The samples were carefully weighed to the nearest tenth of a gram before and after oven drying. For the studies in the Klamath River Basin, two thermostatically controlled electric ovens were used for the purpose of drying the samples. The drying process required approximately 24 hours at a temperature of 110° C. This relatively low temperature for a long period assured complete drying without oxidation of vegetable matter in the soil or evaporation of molecular water. Table B-5 is typical of a field and laboratory data sheet for Plot 30.

For computation and presentation purposes, the soil moisture content was expressed as equivalent inches depth of water. This computation necessitated knowledge of the apparent specific gravity of each soil depth zone. At several times during the irrigation season, in a manner similar to the previously described sampling procedure, soil samples were taken for the specific purpose of evaluating the apparent specific gravity of the soil. Greater care was taken in measuring the depth of the sample and in transferring the entire core to a sampling can, but otherwise the procedure of sampling, weighing, and drying was the same. The volume of the soil core was computed, and, by comparing the dry weight of the soil core to that of an equal volume of water, a measurement of the apparent specific gravity was made. The results for Plot 30 and the conversion of soil moisture content in percentage to equivalent inches depth of water is shown on Table B-5. After each sampling, the determined soil moisture percentages were converted to equivalent inches depth of water and plotted on graph paper. Plate B-1 shows the soil moisture depletion graph for Plot 30 during the 1954-1955 season. The values of soil moisture at times of sampling as plotted on the graph are connected by lines. Dates of irrigation are indicated by vertical solid lines indicating increase in soil moisture content. The slopes of the lines following irrigation and precipitation indicate rates of consumptive use of water. Thus, the sum of the ordinates of the sloping lines represents the amount of total consumptive use of water for any period. The graphical plotting of the sampled points permitted allowance for microvariations in soil texture, in water holding capacity, and in distribution of applied water, whenever three or more points were obtained between

TABLE B-1

LOCATION AND DESCRIPTION OF SOIL MOISTURE DEPLETION PLOTS, IRRIGATED CROPS

Plot number	Owner	Crop	Year of sampling	Location (referenced to Mt. Diablo Base and Meridian) [a]	Method of irrigation	Soil type	Sampling depth, in inches	Effective root depth, in inches
Scott Valley								
1A	Orrin Heinke	Pasture	1953	T43N, R9W, S2E	Border check	Vina loam	60	36
2	Orrin Heinke	Barley	1953	T43N, R9W, S3A	Furrow	Vina sandy loam	60	48
2B	Orrin Heinke	Wheat	1954	T43N, R9W, S3A	Furrow	Vina sandy loam	60	48
6	Glenn Barnes	Pasture	1953, 1954	T40N, R8W, S17D	Wild flooding	Altamont loam	36	30
7A, 7B	Howard Towne	Alfalfa	1953, 1954	T40N, R8W, S24H	Wild flooding	Altamont gravelly loam	72	72
Shasta Valley								
20	Tom Williams	Alfalfa and grasses	1953	T45N, R6W, S13C	Wild flooding	Montague clay loam adobe	60	36
21	C. C. Dougherty & Sons	Wheat	1954	T43N, R6W, S22F	Sprinkler	Elder gravelly sandy loam	60	60
22	A. N. Johnson	Alfalfa	1953	T45N, R5W, S20L	Wild flooding	Agate sandy loam	30	27
23	Henry Silva	Pasture	1953	T44N, R5W, S34H	Border check	Vina fine sandy loam	60	36
24	Henry Silva	Alfalfa	1953, 1954	T44N, R5W, S34G	Border check	Vina sandy loam	60	60
25	Henry Silva	Oats	1953	T44N, R5W, S34J	Border check	Vina fine sandy loam	60	60
26	Vern Burbank	Pasture	1953, 1954	T44M, R6W, S15G	Wild flooding	Altamont loam	36	36
29	Henry Silva	Oats	1954	T44N, R6W, S34K	Border check	Vina sandy loam	60	60
30	C. C. Dougherty & Sons	Alfalfa	1954	T43N, R6W, S22L	Sprinkler	Elder gravelly sandy loam	72	72
Butte Valley								
43	Rex Gritzmaker	Alfalfa	1953	T46N, R2W, S13Q	Border check	Hard sand over hardpan	30	30
44	Rex Gritzmaker	Pasture	1953	T46N, R2W, S14Q	Border check	Fine sand over hardpan	24	24
46	Delos Mills	Alfalfa	1953, 1954	T45N, R2W, S3F	Border check	Shasta gravelly sand	60	60
47, 47B	Delos Mills	Alsike clover	1953, 1954	T45N, R2W, S3G	Border check	Shasta gravelly sand	60	36
49	R. L. Meglasson	Barley	1953	T46N, R1E, S7C	Border check	Ager sandy loam	60	36
53	Mr. Kandra	Barley	1953	T46N, R1W, S33F	Sprinkler	Modoc sand	60	36
54	R. L. Meglasson	Oats	1954	T46N, R1E, S7H	Border check	Ager sandy loam	60	36

[a] Terminal letter refers to 40-acre plots subdividing a section. Letters advance alphabetically, except for I and O, from northeast quarter of northeast quarter in the same manner as sections are numbered.

TABLE B-2

LOCATION AND DESCRIPTION OF SOIL MOISTURE DEPLETION PLOTS, NON-IRRIGATED CROPS AND NATIVE VEGETATION

Plot number	Species or crop	Period of sampling	Location (referenced to Mt. Diablo Base and Meridian) [a]	Soil type	Effective root zone, in inches	Average soil depth in plot area, in inches	Ground slope at plot, in per cent
Scott Valley							
3	Barley	Spring '54-Spring '55	T42N, R9W, S12K	Modoc gravelly loam	60	48-	0-5
11	Ponderosa pine, 60 year	Fall '53-Spring '55	T41N, R8W, S36N	Maymen clay loam	36	18-24	10-15
12	Ceanothus and sagebrush	Fall '53-Spring '55	T42N, R9W, S13G	Sandy loam	48	18-24	10-15
13	Ponderosa pine	Fall '53-Spring '55	T41N, R9W, S6K	Siskiyou gravelly loam	60	18-24	50-60
Shasta Valley							
27	Permanent pasture	Spring '54-Spring '55	T45N, R5W, S16F	Lassen clay loam	36	24-36	15-20
28	Oats	Spring '54-Spring '55	T45N, R5W, S16C	Lassen clay loam	30	24-30	15-20
31	Tarweed, poa, eriogonum	Fall '53-Spring '55	T45N, R7W, S23M	Lassen clay loam	60	36-	5-10
32	Ceanothus and mountain mahogany	Fall '53-Spring '55	T45N, R7W, S3K	Maymen loam	48	36-42	20-25
33	Manzanita	Fall '53-Spring '55	T42N, R7W, S26E	Sites gravelly loam	48	36-42	25-30
34	Ponderosa pine and Garry oak, 25 year	Fall '53-Spring '55	T42N, R7W, S27Q	Laughlin gravelly loam	72	18-24	40-50
35	Borage and brome	Fall '53-Spring '55	T45N, R5W, S6	Montague clay loam adobe	36	36-	0
Butte Valley							
51	Wheat	Fall '53-Spring '55	T46N, R1W, S15A	Lassen clay loam	24	18-24	0
52	Wheat stubble	Fall '53-Spring '55	T46N, R1W, S14D	Lassen clay loam	24	18-24	0
56	Sagebrush and rubber rabbit brush	Fall '53-Spring '55	T46N, R1W, S14D	Lassen loam, wind modified	48	24-36	0
57	Ponderosa pine, 60 to 80 year	Fall '53-Spring '55	T45N, R2W, S35N	Butte loam	60	48-60	0-5

[a] Terminal letter refers to 40-acre plots subdividing a section. Letters advance alphabetically, except for I and O, from northeast quarter of northeast quarter in the same manner as sections are numbered.

TABLE B-3

OBSERVED CONSUMPTIVE USE OF WATER BY IRRIGATED CROPS AT SOIL MOISTURE DEPLETION PLOTS, 1953 AND 1954

Plot number	Valley in which plot is located	Season	Crop	Number of irrigations	Sampling depth, inches	Observed consumptive use, in inches depth of water							
						April 15-30	May	June	July	August	September	October 1-15	Totals
7A	Scott	1953	Alfalfa	5	72	1.3	2.7	3.5	7.6	5.6	3.9	1.0	25.6
7B	Scott	1954	Alfalfa	4	72	1.0	5.2	3.3	5.7	4.6	3.2	0.6	23.6
22	Shasta	1953	Alfalfa	7	30	1.5	3.0	3.7	5.7	5.8	3.1	0.3	23.1
24	Shasta	1953	Alfalfa	5	60	0.9	2.2	6.2	9.7	8.0	5.1	0.9	33.0
24	Shasta	1954	Alfalfa	6	60	1.7	6.0	5.1	8.2	6.8	4.0	0.5	32.3
30	Shasta	1954	Ahalfa	6	72	1.0	5.9	1.7	6.9	5.3	4.3	1.3	26.4
43	Butte	1953	Alfalfa	3	30	0.6	3.2	3.7	6.6	3.6	3.4	0.4	21.5
46	Butte	1953	Alfalfa	4	60	0.9	4.9	5.2	6.3	5.5	4.4	0.8	28.0
			Average, alfalfa										26.7
1A	Scott	1953	Pasture	9	60	2.0	4.0	6.1	7.1	7.1	6.2	0.6	33.1
6	Scott	1953	Pasture	9	30	1.7	3.5	5.4	7.0	3.8	2.7	0.9	25.0
6	Scott	1954	Pasture	13	36	2.5	5.7	5.2	5.6	6.9	4.8	1.2	31.9
23	Shasta	1953	Pasture	9	60	1.6	4.1	4.8	7.8	6.8	4.6	1.3	31.0
26	Shasta	1953	Pasture	14	36	0.6	3.6	5.2	8.6	6.8	6.2	0.9	31.9
26	Shasta	1954	Pasture	15	36	1.8	4.1	4.4	5.6	5.6	4.1	1.1	26.7
44	Butte	1953	Pasture	5	24	0.5	1.2	4.4	7.2	5.2	4.4	0.2	23.1
			Average, pasture										29.0
2	Scott	1953	Barley	2	60	---	2.8	3.2	6.8	2.3	---	---	15.1
49	Butte	1953	Barley	3	60	---	0.4	1.6	4.9	1.8	---	---	8.7
53	Butte	1954	Barley	4	60	---	2.8	5.9	4.7	1.0	---	---	14.4
2B	Scott	1954	Wheat	2	60	---	2.5	4.8	4.5	1.0	---	---	12.8
21	Shasta	1954	Wheat	2	60	---	3.7	3.2	1.6	0.1	---	---	8.6
25	Shasta	1953	Oats	3	60	---	1.9	8.6	3.6	2.1	---	---	16.2
29	Shasta	1954	Oats	3	60	---	0.5	5.0	9.1	4.4	---	---	19.0
54	Butte	1954	Oats	6	60	---	1.8	3.9	6.9	2.4	---	---	15.0
			Average, grains										13.7
20	Shasta	1953	Seed Grasses and alfalfa	4	60	2.2	3.6	5.9	8.2	6.0	2.3	0.2	28.4
47	Butte	1953	Seed Alsike clover	7	60	0.6	3.4	5.1	7.2	6.3	2.9	0.5	26.0
47B	Butte	1954	Seed Alsike clover	8	60	1.6	4.1	5.5	6.3	4.5	3.7	0.1	25.8
			Average, seed crops										26.7

TABLE B-4

OBSERVED CONSUMPTIVE USE OF WATER BY NON-IRRIGATED CROPS AND NATIVE VEGETATION AT SOIL MOISTURE DEPLETION PLOTS, 1954

Plot number	Valley in which plot is located	Species or crop	Sampling depth, inches	Observed consumptive use, in inches depth of water							
				March	April	May	June	July	August	September	Totals
		Trees									
11	Scott	Ponderosa pine, 60 year	48	2.7	2.5	1.8	2.4	1.4	0.4	0.3	11.5
13	Scott	Ponderosa pine	60-66	3.8	4.2	4.4	2.0	0.6	0.2	0.2	15.4
34	Shasta	Ponderosa pine and Garry oak, 25 year	60-72	2.1	2.7	2.1	2.2	2.1	0.9	0.4	12.5
57	Butte	Ponderosa pine, 60-80 year	72	1.2	2.4	2.3	3.0	1.7	0.6	0.4	11.6
		Shrubs									
12	Scott	Ceanothus and sagebrush	48	1.6	2.8	1.1	1.6	0.8	0.2	0.5	8.6
32	Shasta	Ceanothus and Mountain mahogany	48	1.6	2.7	2.0	2.6	1.3	0.9	0.1	11.2
33	Shasta	Manzanita	48	2.0	2.3	1.5	1.5	1.4	0.9	0.7	8.5
56	Butte	Sagebrush and robber rabbit brush	48	1.0	1.3	1.2	2.2	1.4	0.5	0.5	8.1
		Grasses									
31	Shasta	Tarweed, poa, eriogonum	72	1.8	2.4	2.4	2.2	0.7	0.7	0.4	10.6
35	Shasta	Borage and brome	60	2.5	2.3	1.2	1.0	0.9	0.3	0.2	8.4
		Non-irrigated Crops									
27	Shasta	Permanent pasture	48	1.0	1.9	1.1	1.2	0.8	0.2	0.2	6.4
28	Shasta	Oats	30	0.4	2.2	2.2	1.5	0.8	0.4	0.6	8.1
51	Butte	Wheat	24	1.3	2.9	1.6	1.2	0.4	0.4	0.4	8.2
3	Scott	Barley	60	0.7	1.6	2.4	0.8	0.8	0.5	0.4	7.2
		Stubble									
52	Butte	Wheat Stubble	24	1.0	2.2	1.5	0.7	0.7	0.6	0.6	7.3

TABLE B-5

EXAMPLE OF FIELD AND LABORATORY DATA SHEET FOR SOIL MOISTURE SAMPLES

Crop: *Irrigated alfalfa*

Plot number: *30*
Date sampled: *April 12, 1954*
Owner: *C. C. Dougherty*
Date of previous irrigation: *March 5, 1954*

Hole number	Stratum	Can number	Weight of sample, in grams		Loss of water, in grams	Soil moisture, in percent of dry weight of soil
			Wet soil	Dry soil		
1	0-1	145	181.8	165.0	16.8	10.2
1	1-2	146	205.5	187.3	18.2	9.7
1	2-3	147	164.4	153.9	10.5	6.8
1	3-4	148	177.3	168.4	8.9	5.3
1	4-5	149	182.8	172.9	9.9	5.7
1	5-6	150	190.6	181.2	9.4	9.4
2	0-1	151	196.9	176.4	20.5	11.6
2	1-2	152	172.2	156.7	15.5	9.9
2	2-3	153	184.2	172.0	12.2	7.1
2	3-4	154	152.5	145.0	7.5	5.2
2	4-5	155	153.5	146.0	7.5	5.1
2	5-6	156	131.2	123.5	7.7	6.2
3	0-1	157	199.6	182.5	17.1	9.4
3	1-2	158	180.0	165.8	14.2	8.6
3	2-3	159	165.9	155.8	10.1	6.5
3	3-4	160	173.2	165.7	7.5	4.5
3	4-5	161	188.7	179.6	9.1	5.1
3	5-6	162	174.0	165.1	8.9	5.4

EQUIVALENT MOISTURE CONTENT, AVERAGE FOR ALL HOLES SAMPLED

Stratum	Soil moisture, percent of dry weight	Apparent specific gravity	Equivalent moisture content, inches depth of water
0-1	10.4	1.29	1.61
1-2	9.4	1.42	1.60
2-3	6.8	1.36	1.11
3-4	5.0	1.32	0.79
4-5	5.3	1.48	0.94
5-6	5.6	1.45	0.97
Total			7.02

irrigations. Whenever precipitation occurred during the sampling period an adjustment was made graphically to allow for moisture placed into the soil. When the plots were not within the vicinity of a standard precipitation gage, precipitation gages were maintained near the plot by State field personnel.

The procedure for determining unit values of consumptive use of water by irrigated crops is discussed in Chapter III of this report. This procedure involved the use of the formula $U = KF$: where U equals consumptive use of the water in inches for any period, K equals an empirical consumptive use of water coefficient, and F equals the sum of the monthly consumptive factors for the period (sum of the products of mean monthly temperature and monthly per cent of annual daylight hours). Using the observed consumptive use of water on irrigated plots for the growing season as shown in Table B-3, the mean monthly temperature at a nearby weather station and the monthly per cent of annual daylight hours at the latitude of the plot, the consumptive use coefficient for the growing season was determined for each plot. These values and the averages for each crop investigated are shown in Table B-6.

In conclusion, the results of the consumptive use studies under this investigation agree favorably with previously established data. The average consumptive use coefficients were determined herein to be 0.80 for alfalfa, 0.85 for improved pasture, 0.80 for alfalfa mixed with grasses and 0.85 for Alsike clover. These values agree with consumptive use coefficients published in the United States Department of Agriculture Soil Conservation Service bulletin, "Determining Water Requirements in Irrigated Areas from Climatological and Irrigation Data," by Harry F. Blaney and Wayne D. Criddle, 1950. Coefficients listed for irrigated crops include 0.80 to 0.85 for alfalfa, 0.75 for grass pasture, and 0.80 to 0.85 for ladino clover pasture. Studies over a period of years at Davis, California, show the normal consumptive use of alfalfa during the growing season, April 1 to October 31, to be about 45 inches whereas these studies in the

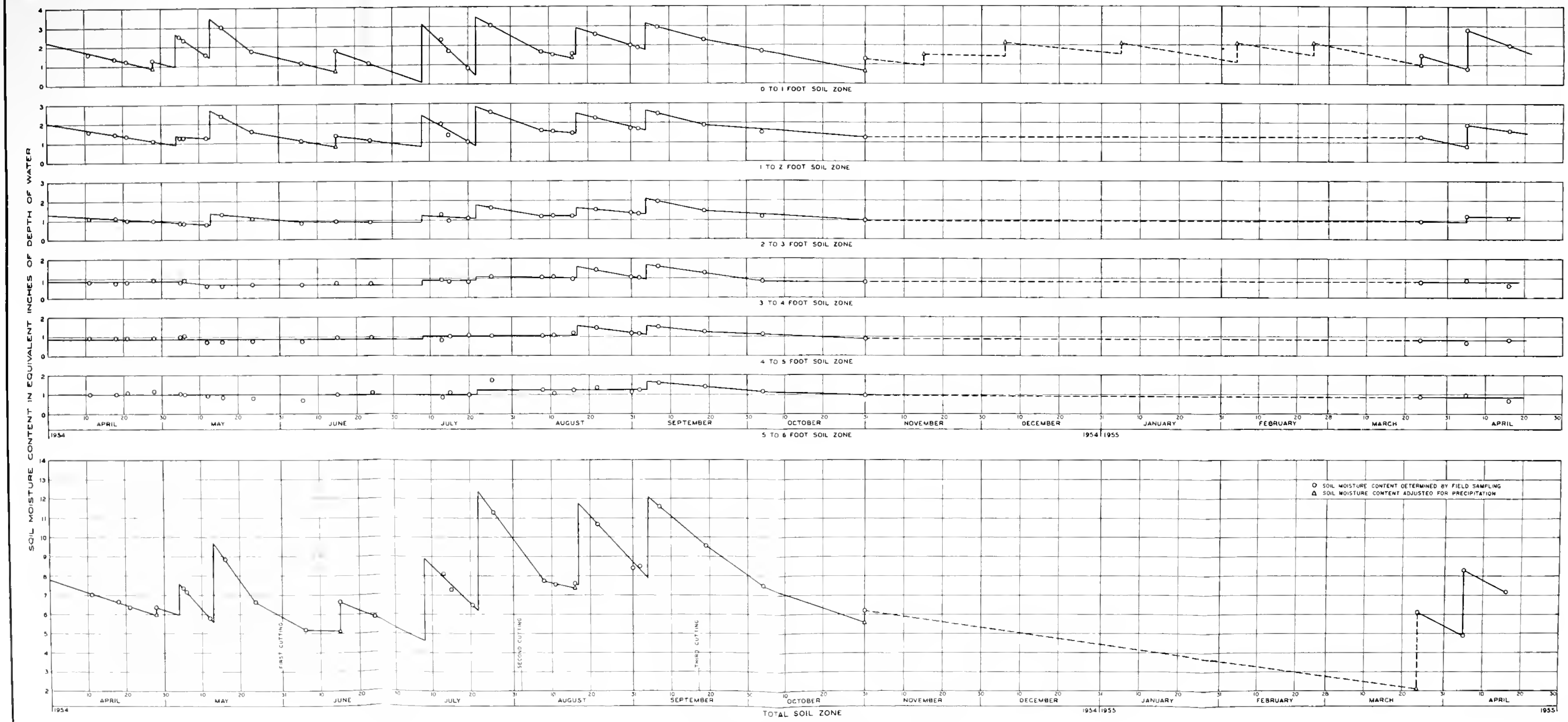
Klamath River Basin show average growing season consumptive use of alfalfa to be about 27 inches. In the Klamath River Basin, a growing season shorter by about one month and the generally cooler temperature, may account for this difference.

Consumptive use coefficients were determined in this study for irrigated small grains to be 0.55 for barley, 0.40 for wheat, and 0.65 for oats. These values are considerably less than the general coefficient ranging from 0.75 to 0.85 for small grains as listed in the above Department of Agriculture publication. A coefficient of 0.68 based on a consumptive use of 12.0 inches during a three-month period is listed in the above bulletin as the result of studies at Davis, California.

TABLE B-6

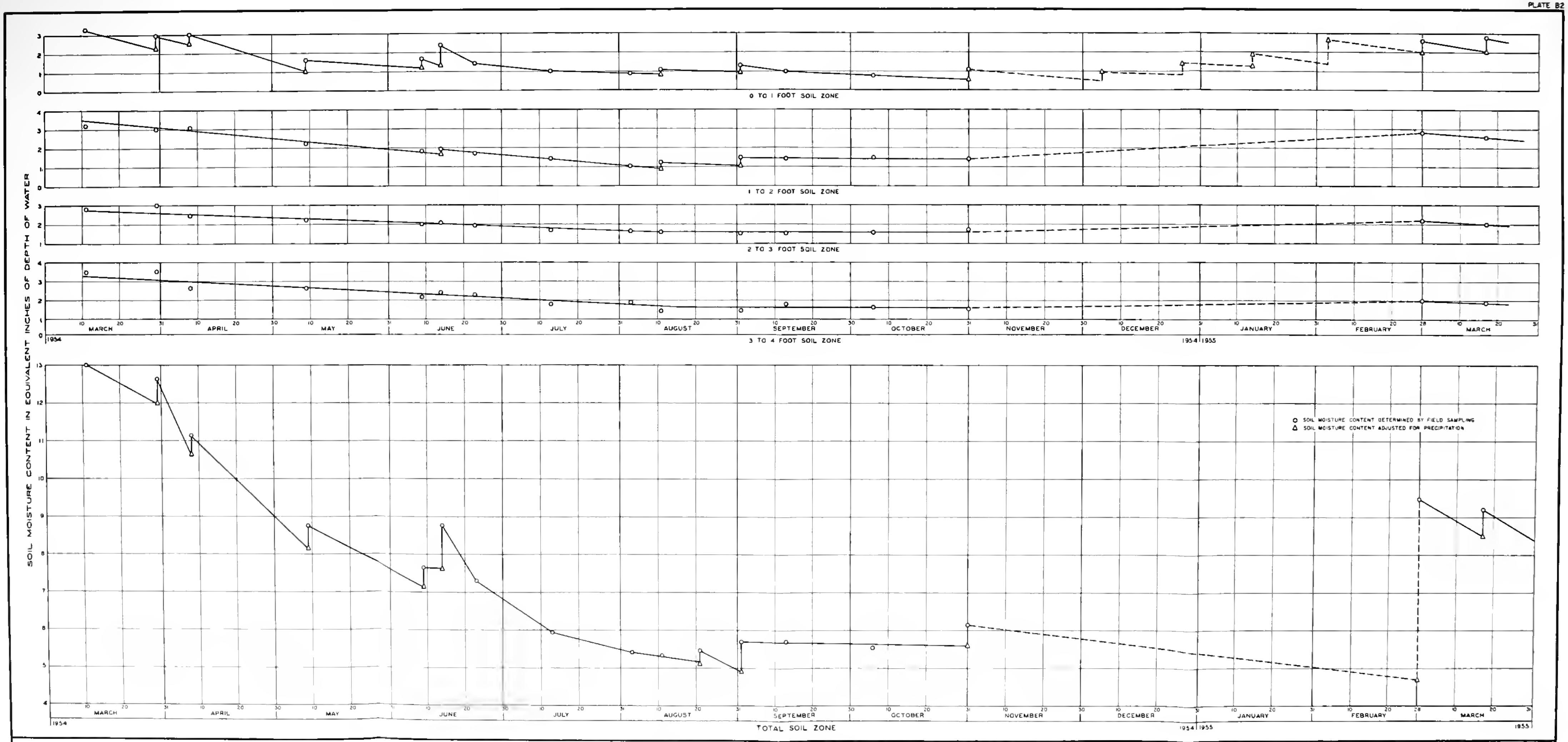
COEFFICIENTS OF CONSUMPTIVE USE OF WATER BY IRRIGATED CROPS, DETERMINED FROM SOIL MOISTURE DEPLETION PLOT STUDIES DURING 1953 AND 1954

Crop	Plot number	Irrigation season	Location of plot	Type of irrigation	Growing season	Effective root depth, in inches	Observed consumptive use of water, in inches of depth: U	Consumptive use factor for corresponding season: F	Consumptive use coefficient: K	Approximate average
Alfalfa	7B	1953	near Callahan	wild flooding	4/15–10/15	72	25.6	34.3	0.75	
	7B	1954	near Callahan	wild flooding	4/15–10/15	72	23.6	34.3	0.69	
	22	1953	near Montague	wild flooding	4/15–10/15	27	23.1	35.0	0.66	
	24	1953	near Big Springs	border check	4/15–10/15	60	33.0	35.0	0.94	
	24	1954	near Big Springs	border check	4/15–10/15	60	32.3	35.5	0.91	
	30	1954	near Gazelle	sprinkler	4/15–10/15	72	26.4	35.5	0.74	
	43	1953	near Macdoel	border check	4/15–10/15	30	21.5	30.9	0.70	
	46	1953	near Macdoel	border check	4/15–10/15	60	28.0	30.9	0.91	
										0.80
Improved pasture	1A	1953	near Fort Jones	border check	4/15–10/15	36	33.1	34.3	0.96	
	6	1953	near Callahan	wild flooding	4/15–10/15	30	25.0	34.3	0.73	
	6	1954	near Callahan	wild flooding	4/15–10/15	30	31.9	35.4	0.90	
	23	1953	near Big Springs	border check	4/15–10/15	36	31.0	35.0	0.89	
	26	1953	near Grenada	wild flooding	4/15–10/15	36	31.9	35.0	0.91	
	26	1954	near Grenada	wild flooding	4/15–10/15	36	26.7	35.5	0.75	
	44	1953	near Macdoel	border check	4/15–10/15	24	23.1	30.9	0.75	
										0.85
Barley	2	1953	near Fort Jones	furrow	5/1–8/31	48	15.1	24.3	0.62	
	49	1953	near Macdoel	border check	5/1–8/31	36	8.7	21.8	0.40	
	53	1954	near Macdoel	sprinkler	5/1–8/31	36	14.4	22.5	0.64	
										0.55
Wheat	2B	1954	near Fort Jones	furrow	5/1–8/31	48	12.8	25.1	0.51	
	21	1954	near Gazelle	sprinkler	5/1–8/31	60	8.6	25.7	0.33	
										0.40
Oats	25	1953	near Big Springs	border check	5/1–8/31	60	16.2	24.7	0.66	
	29	1954	near Big Springs	border check	5/1–8/31	60	19.0	25.7	0.74	
	54	1954	near Macdoel	border check	5/1–8/31	36	15.0	22.5	0.67	
										0.70
Alfalfa and grass	20	1953	near Montague	wild flooding	4/15–10/15	36	28.4	35.0	0.81	
										0.80
Alsike clover	47	1953	near Macdoel	border check	4/15–10/15	36	26.0	30.9	0.84	
	47B	1954	near Macdoel	border check	4/15–10/15	36	25.8	30.7	0.84	
										0.85



SOIL MOISTURE DEPLETION AND ACCRETION
PLOT 30, IRRIGATED ALFALFA
SHASTA VALLEY

DEPARTMENT OF WATER RESOURCES 1959



SOIL MOISTURE DEPLETION AND ACCRETION

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SHASTA VALLEY

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APPENDIX C

MUNICIPAL WATER CONSUMPTION

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APPENDIX C

MUNICIPAL WATER CONSUMPTION

TABLE C-1

MUNICIPAL WATER CONSUMPTION IN THE KLAMATH RIVER BASIN

City or town	Company	Period of record	Total annual consumption, in million gallons	Total number of persons served	Per capita consumption, in gallons per day	Remarks
California						
Fort Jones	Dunsmuir Water Corp.	1953	32.3	500	177	Master meter on pump which fills reservoir; data includes distribution losses
		1952	33.4	500	183	
		1951	33.5	500	184	
Yreka	Municipal	1950-1953	355.6	3,200	304	Estimates of gross diversion by city water engineer; data include distribution losses
Weed	Shastina Water Co.	1951	90.0	1,800	137	Sum of meter readings on individual services
Montague	Municipal	9/1/52-9/1/53	[1]38.3	600	175	Meter on chlorinator, data include distribution losses
Hilt	Fruit Growers Assoc.	July, August, September, 1953	----------	468	127	Sum of meter readings on individual services
Dorris	Municipal	1952	164.6	956	472	Estimates of gross pumpage by city engineers, data include distribution losses
Tulelake	Municipal	7/1/50-6/30/51	[1]35	1,100	105	Sum of meter readings on individual services
		7/1/49-6/30/50	[1]42	1,028	134	
Dunsmuir	Dunsmuir Water Corp.	1953	408.2	3,000	373	Master meter on pump which fills reservoir; data include distribution losses
		1952	367.5	3,000	336	
		1951	316.6	3,000	289	
Hornbrook	Hornbrook Water Co.	Average for 1945-49 inclusive	43.2	275	430	Sum of meter readings on individual services
Weaverville	Weaverville Water Co.	1953	20.2	522	106	Sum of meter readings on individual services, based on 3 persons per meter
		1952	18.7	453	113	
		1951	12.5	186	139	
		1950	6.1	99	170	
Terwar Valley	Macbeth Water Co.	1953	7.3	300	67	Estimate by owner of gross flow from spring into system; checked against sum of meter readings on 40 per cent of system, based on 3 persons per meter
Oregon						
Klamath Falls	Oregon Water Co.	1953	1,684.3	26,000	177	Master meters on pumps supplying distribution tanks; data include distribution losses
		1952	1,809.0	26,000	191	
		1951	1,908.4	26,000	201	
Bly	Bly Water Co.	1952-1953	45.6	650	192	Observations by owner of fluctuations of float setting on storage tank; data include distribution losses
Merrill	Municipal	Based on August 1953	61.7	835	202	Sum of meter readings on individual services for month of August. August use equals 14 per cent of annual based on monthly use in other Klamath Basin cities
Malin	Municipal	7/1/51-6/30/52	[1]51.3	600	234	Sum of meter readings on individual services

NOTE: Municipal water consumption for all cities and towns except Hilt includes domestic, industrial, commercial, and public uses. Record for Hilt includes domestic only.
[1] Water consumption for period indicated.

APPENDIX D

FISH, GAME, AND RECREATION IN THE KLAMATH RIVER BASIN OF CALIFORNIA

By

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under the direction of

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California Department of Fish and Game

December, 1956
(Revised December, 1958)

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APPENDIX D

FISH, GAME, AND RECREATION IN THE KLAMATH RIVER BASIN OF CALIFORNIA

INTRODUCTION

The Klamath River Basin is one of the most widely known fishing, hunting, and recreational areas in the United States. Klamath River, from Copco Dam for 185 miles to the sea, is an outstanding sport fishing stream and, along with its principal tributary, the Trinity River, is world famous among sportsmen for its excellent salmon and steelhead fishing. Deer and migratory waterfowl hunting excel in the upper basin. The Klamath River system also encompasses two of the few remaining primitive recreational areas in California—the Marble Mountains Wilderness Area and the Salmon-Trinity Alps Wilderness Area. Great numbers of sportsmen and tourists come from all sections of California, other states, and even from other countries to fish and hunt in the Klamath River system. These people contribute substantially to the economy of the basin and California .

Although recreational use of the Klamath River Basin is considerable at present, there is still a tremendous potential use to be developed. As the State's population grows, the Klamath River will assume an increasingly greater role in furnishing outdoor recreation. By contrast, many sections of California are rapidly approaching a condition of maximum use, as far as hunting and fishing are concerned, due primarily to limited available area and to water scarcity.

In recent years California has experienced a phenomenal increase in population. The 1950 census showed that 10,586,000 people were living in the State, a 100 per cent increase in two decades. In 1955 the population passed 13,000,000, and by 1960 it is estimated that California's population will be 15,650,000. Time spent by Californians seeking outdoor sports and recreation is almost twice the national average according to surveys. The same ratio would probably hold true for cash expenditures by those seeking outdoor recreation. The annual harvest of fish and game throughout the State has increased 30 times that of 40 years ago. Total angling license sales doubled between 1935 and 1941, and then promptly redoubled between 1941 and 1948. In 1955, 1,800,000 licensed California anglers spent 22,700,000 angler-days fishing in California waters—15,600,000 of these days were spent on fresh-water streams and lakes. The nearly two million hunters and anglers who now purchase licenses in California are estimated to be spending more than $250 each annually in pursuit of fish and game. Fishing and hunting pressures within the Klamath River drainage probably increased at least in proportion to that of the State as a whole, and it is assumed that these figures indicate, more or less, the increased hunting and fishing pressure within the Klamath Basin as well as within the whole of California. Table D-1 shows the increase in hunting and fishing in California between 1920 and 1950 based on hunting and fishing license sales, compared with increases in the State's population over the same period of years.

TABLE D-1

HUNTING AND FISHING LICENSES SOLD IN CALIFORNIA COMPARED WITH POPULATION INCREASES, 1920 TO 1950

Year	Population census		Hunting and fishing licenses sold and issued		Ratios of licenses to population
		Increase		Increase	
1920	3,427,000		383,785		1:9
		2,250,000		96,494	
1930	5,677,000		480,279		1:12
		1,230,000		201,570	
1940	6,907,000		681,849		1:10
		3,679,000		792,594	
1950	10,586,000		1,474,443		1:7.2

The people of California are well aware of the importance of the Klamath River as a recreational area, and in 1924, by an initiative measure adopted by an overwhelming majority of the ballots cast, voted to create a special fish and game district of this river from its confluence with the Shasta River to the sea. The provisions of this law prohibit construction of dams on this section of the Klamath River proper. (Fish and Game Code Section 11036.) Commercial fishing for salmon and steelhead was halted in the Klamath River by the State Legislature at the end of 1933. (Fish and Game Code Section 8434.) This river has thus been set aside for the recreational enjoyment of all the people.

Purpose and Scope of Report

The purpose of this report is to present available data concerning the fish and game resources, including their importance and water requirements, and recreational use of the Klamath River Drainage Area in California. The importance of this area from a recreational use standpoint is discussed; however, a complete economic evaluation of the wildlife resources is not intended and is beyond the scope of this report. The figures presented give some idea of the magnitude of these wildlife resource values. Estimated water requirements to maintain fishing and hunting are discussed generally for the entire area. Specific minimum water requirements for fish in the more important streams and for migratory waterfowl refuges are also presented.

A section discussing proposed local development reservoirs is included, as is a discussion of the export plans proposed for the Klamath River Basin.

FISHING

Early History

The Klamath River and its largest tributary, the Trinity River, have been fishing grounds for Indian tribes for many years. In the past, thousands of salmon and steelhead were caught annually by Indians living in the Klamath and Hoopa territories. A dipnet fishery, principally for salmon, existed at Ishi Pishi Falls, just above the mouth of the Salmon River. Quantities of candlefish were also netted in the lower river. The Indians constructed fish weirs of logs, poles, and brush across the Klamath and Trinity Rivers, then speared or netted the upstream migrant salmon, steelhead, and even Pacific lampreys. Some of these weirs, such as those constructed by the Hoopa Indians on the Trinity River, remained in the stream as virtually impassable barriers until the first rains of autumn replenished river flows sufficiently to wash them away. Others, such as those constructed by the Yuroks across the Klamath River at Kelpel, were removed by the Indians after an exact number of days in place. Year after year these weirs were installed according to strict ritual and procedures. In more modern times fish weirs have disappeared entirely on the Klamath River, with the one across the Trinity River at Hoopa being the last to disappear.

A vigorous commercial fishery for salmon began on the lower Klamath River shortly after gold mining started. Early fishing efforts were for local supplies. Later, however, canneries began operating on the Klamath Estuary and reached a high state of development by 1912. Very little exact information exists concerning commercial fishing operations on the Klamath River previous to 1912, and no dependable statistics are available relating to catches before that time. Early records indicate that a historical peak in the Klamath River commercial fishery occurred in 1912 when over 1,387,000 pounds of fish were packed. The commercial fishery for salmon and steelhead was abolished by legislation at the end of 1933.

Two dams on the Klamath River about 12 miles downstream from the Oregon border, one forming Copco Lake and another one-quarter mile farther downstream, prevent migration of anadromous fishes to the area upstream. There are about eight miles of stream between the head of Copco Lake and the Oregon border. In accordance with the provisions of law which require owners of dams to erect hatcheries in lieu of fishways when dams are too high for the successful operation of a fishway, or when for other reasons it is impractical to install a fishway (Section 5938 Fish and Game Code), the California-Oregon Power Company, owner of Copco Dams, was required to build and equip a salmon hatchery on Fall Creek in 1924. Fall Creek hatchery was operated by the California Department of Fish and Game until 1948, when its production was taken over by other hatcheries.

Further water and power development projects were blocked on Klamath River proper in 1924 by an initiative measure sponsored by the California Fish and Game Commission. The text of the act is as follows:

> "Section 1. The Klamath River Fish and Game District is hereby created and shall consist of the Klamath River and the waters thereof, following its meanderings from the confluence of the Klamath River and the Shasta River in the County of Siskiyou to the mouth of the Klamath River in Del Norte County.
>
> "Section 2. Every person, firm, corporation or company who constructs or maintains any dam or other artificial obstruction in any of the waters of said Klamath River Fish and Game District is guilty of misdemeanor and upon conviction must be fined not less than five hundred dollars ($500) or be imprisoned in the county jail of the county in which the conviction shall be had not less than 100 days, or both such fine and imprisonment, and any artificial obstruction constructed, placed or maintained in said district is hereby declared a public nuisance."

Present Conditions

Streams of the Klamath watershed, like many of our coastal streams, are subject to considerable natural fluctuation due to the existence of a wet winter season and a dry summer season each year. Unfavorable conditions due to natural low water are greatly accentuated by the operation of diversions for irrigation, power, and domestic use. Irrigation ditches are the most common diversions and create the greatest problem at present. They are operated mostly during spring and summer when young steelhead and salmon and surviving adult steelhead are on their downstream migration to the ocean, or the remaining fish are struggling for existence in drying streams. In the past, many diversions were also used in connection with gold mining operations. At present gold mining activity is greatly reduced in the Klamath River Basin and is negligible except for dredge mining in the Trinity River near Minersville.

Present dams and power plants on the Klamath River proper have created fluctuating flows detrimental to fish life as well as a threat to human life, a situation which requires remedial action in the near future.

Game Fishes of the Klamath River System

Most important streams in the Klamath River drainage are accessible by road or trail somewhere along their courses. The greatest amount of angling in streams of the Klamath watershed is for three species

of fish—steelhead rainbow trout, king salmon, and silver salmon. During spring and early summer, fishing is carried on for young steelhead and to some extent for young silver salmon. Then during the summer and autumn there is considerable angling in the Klamath Estuary and lower reaches for both species of adult salmon and for adult steelhead.

Adult king salmon enter the Klamath River from the ocean in two well defined runs, one in spring and another in fall. The spring run begins in late March, reaches a peak in May, and diminishes to the vanishing point by the end of June. At present this run is small. The summer (fall) run usually begins entering the Klamath Estuary about the first of July. It increases gradually throughout that month, reaches a peak in August, declines steadily through September, and practically disappears by the beginning of winter.

As spawning runs of salmon and steelhead proceed up the Klamath River and branch out into its tributaries, great numbers of sportsmen come from all over California, and from other states as well, to fish for them. The sport fishery for adult steelhead is most intensive on the lower Klamath River in early fall, but is pursued throughout the basin, particularly in the Trinity River, over the entire open season—May through February.

Other species are also sought by anglers in the Klamath River drainage and they contribute substantially to the recreational value of the area. Coast cutthroat trout, an anadromous form, are taken in lower tributary streams such as Panther, High Prairie, and Hunter Creeks. The Klamath Mountains encompass a large number of streams and natural lakes which offer excellent trout fishing. Included in the Klamath Mountains are the Marble Mountains Wilderness Area and the Trinity Alps and Trinity Divide Areas, whose streams and lakes are noted for their fine fishing. Eastern brook trout and resident rainbow trout predominate in these higher lakes and streams. Brown trout are also present in the Klamath River and in many tributaries.

There is some angling for brown bullheads in mining dredge holes along the Klamath River, particularly during the winter months. Shasta River, especially in Shasta Valley, is a very popular stream for bullhead anglers. Green sunfish, bluegill, and pumpkinseed sunfish are also caught by fishermen, and make a small contribution to the angler's catch each year. Yellow perch, a comparative newcomer to the Klamath River in California, enters the sport fishery in various numbers, usually during the warm summer months. Yellow perch were introduced into tributary waters of the Klamath River in Oregon and have gradually worked their way downstream. Largemouth bass also are present in the river, but not plentiful. They are found in Copco Lake on the Klamath River and have also been taken in mining dredge ponds directly connected to the Klamath River in the vicinity of Horse Creek. Shad also enter the Klamath River and support a minor fishery during certain years.

Klamath River: Numbers of Anadromous Fishes and Their Spawning Areas

The principal salmon spawning beds in the Klamath River proper are located from the mouth of the Shasta River to the upstream limit of migration at Copco Dam, a distance of approximately 22 miles (Plate 1). Spawning on the main stem of the Klamath River, downstream from its confluence with the Shasta River, is scattered and does not involve large numbers of fish. Larger tributaries, including the Trinity, Salmon, Scott, and Shasta Rivers, as well as a host of excellent smaller tributaries, such as Blue, Clear, Elk, Indian, Beaver, Bogus, and Fall Creeks, contain important spawning beds utilized by salmon and steelhead. Some of these streams have annual spawning runs of both king and silver salmon as well as steelhead. Spring salmon migration in the Klamath River system was once very great, but it has now become reduced and is of considerably less economic importance. As the streams came to be used more and more by man, summer conditions were often made intolerable to the spring run. So even though conditions have remained suitable for fall run fish, spring runs have vanished from some streams and have been greatly diminished in others.

Studies during the 1920's indicated that salmon runs of the Klamath River system as a whole were diminishing, and that further investigation should be made to find means of remedying this condition. Counts of upstream migrant king salmon began in 1925 at Klamathon Racks on the Klamath River, 14 miles below Copco Dam. Five years later a counting rack was installed on Shasta River, near its confluence with the Klamath River, and counts were obtained there also.

The average annual number of king salmon reaching Klamathon Racks during the 22 years in which counts were made is about 12,000. No counts were made during the war years. The bulk of the king salmon utilizing areas upstream from Klamathon usually spawn from October 1 through the early part of November, and the seaward migration of young salmon commences in the latter part of December and continues into early April. Table D-2 gives the counts of adult king salmon at Klamathon Racks from 1925 through 1955.

Very little is known concerning the size of silver salmon runs in the Klamath River. Recently, however, the Department of Fish and Game has accumulated considerable evidence which shows that silver salmon are more abundant than has been generally supposed. Silvers spawn in most tributaries to the Klamath, from those near the mouth, such as High Prairie, Hunter, Turwar, and Blue Creeks, to Fall and Bogus Creeks just below Copco Dam. They utilize many

smaller streams not used by king salmon. Two or three hundred silvers are counted through the Klamathon Racks each year. No attempt has been made to get a complete count of silver salmon at Klamathon, but those that pass through the gates during the king salmon run are counted.

Steelhead utilize practically all tributaries of the Klamath and are without doubt the most widespread of the anadromous fishes in the drainage. The major portion of the steelhead run at Klamathon comes after November 15 and usually after the counting racks have been removed for the season, so no complete accounts are available.

Trinity River: Numbers of Anadromous Fishes and Their Spawning Areas

The Trinity River is the largest and most important tributary of the Klamath River. The lower course of this river is within the Hoopa Indian Reservation. Salmon formerly furnished a considerable and important part of the Hoopa Indian's food along the lower Trinity, although steelhead and Pacific lampreys were also eaten. Lampreys were sought at a time when other fish were not easily taken. Salmon were caught by means of spears and traps, as well as by weirs placed across the river each year.

Gravel of suitable quality for salmon and steelhead spawning is comparatively scarce in the Trinity River proper, downstream from the mouth of the North Fork, due to steep gradient, deep pools, and a boulder-strewn bottom. The numbers of salmon spawning in this lower reach of the Trinity are not known. However, king salmon are known to spawn in Hoopa Valley. Almost without exception, salmon migrating into the Trinity River above the South Fork spawn in the 72 miles of river between the North Fork and Ramshorn Creek 7 miles north of Carrville, as well as in several tributaries. Approximately 80 per cent of the natural spawning area lies above the mouth of Browns Creek near Douglas City, and 50 per cent lies upstream from Lewiston. The most important king salmon spawning tributaries are Stuart Fork, East Fork, South Fork, and Cold Creek.

Adult king salmon migrate past Lewiston enroute to their spawning grounds in what appear to be three seasonal groups; one in spring, one in summer, and another in fall. The spring migration passes Lewiston during June and July; the summer migration during August and September; and the fall migration during October and November. The South Fork of Trinity River has both spring and fall runs of king salmon each year.

The estimated spawning escapement of king salmon in the Trinity River above Canyon Creek in 1955 was nearly 40,000 fish. Further studies in 1956 indicated a run of approximately the same magnitude. Counts by the U. S. Fish and Wildlife Service at the Lewiston Weir between 1942 and 1946 indicate that an average annual run of 12,000 king salmon spawn upstream from Lewiston. The Department of Fish and Game estimated the 1955 king salmon run above Lewiston to be approximately 17,500 fish. No figures are available on the numbers of king and silver salmon utilizing the South Fork and other tributaries of the Trinity River although use of such streams is known to be considerable.

The first signs of spawning activity of spring and summer run salmon are noticeable on the main stem of the Trinity River, usually between the mouth of Grass Valley Creek and the mouth of Stuart Fork, during the first week in October. By the middle of October, activity in this area has usually increased to include all suitable riffles in the Trinity River between the mouth of the North Fork and the mouth of the East Fork of Trinity. Spawning usually reaches a peak during the first two weeks of November when many of the fall run fish are also depositing their eggs. Young king salmon start emerging from the gravel in January and continue through May. The seaward migration of fingerlings begins to intensify in March and reaches a peak in May and June at Lewiston, tapering off to practically nothing by the end of July. Most young king salmon do not spend their first year in streams as do young silvers.

Adult silver salmon enter most lower Trinity River tributaries to spawn. Until recently they were not known to migrate past the mouth of the South Fork;

TABLE D-2

COUNTS OF SALMON AND STEELHEAD AT KLAMATHON RACKS, KLAMATH RIVER

Year	Period of count	King salmon	Silver salmon	Steelhead
1925		10,420		
1926		9,387		
1927		no count		
1928		no count		
1929		4,031		
1930		2,392		
1931		12,611		
1932		13,740		
1933		no count		
1934		10,340		
1935		14,051		
1936		10,398		
1937		33,144		
1938		16,340		
1939		no count		
1940		14,965		
1941		11,204		
1942		13,038		
1943		no count		
1944		no count		
1945		no count		
1946		no count		
1947		no count		
1948	Aug. 30-Nov. 1	5,821		
1949	Aug. 13-Nov. 17	11,504	*541	*2,836
1950	Aug. 7-Oct. 28	21,584	*254	*747
1951	Aug. 10-Oct. 29	17,857	*331	*1,002
1952	Aug. 19-Oct. 29	6,591	*8	*524
1953	Aug. 9-Oct. 28	6,257	----------	*297
1954	Aug. 1-Oct. 30	2,037	*1	*161
1955	Aug. 7-Oct. 21	14,946	----------	*465

* Incomplete counts.

however, during the summers of 1949, 1950, and 1951 silver salmon fingerlings were recovered from fish screen installations near the mouth of Ramshorn Creek; in a Stuart Fork diversion in 1953; and from a fish screen installation on the East Fork in 1954. Spawned-out adult silvers were recovered in Cold Creek in 1955. Silver salmon migrate up the South Fork of the Trinity River to at least the area near Hyampom. Silvers are inclined to spawn in smaller tributaries rather than main streams.

Many adult steelhead utilize the main Trinity River at and above Lewiston as spawning ground. Generally speaking, tributaries rather than the main Trinity River proper are used by steelhead for spawning purposes. Since steelhead spawn in winter and early spring, practically all tributaries have sufficient flows and are available to them in most years. Major steelhead spawning tributaries below Lewiston are Rush, Indian, Reddings, Browns, and Canyon Creeks, and the North and South Forks of Trinity River. Steelhead enter the larger Trinity River tributaries, such as North Fork, Browns Creek, and Stuart Fork, following the first fall rains. Smaller tributaries are entered during the first rains in February, after which these streams maintain a flow sufficient to insure adequate spawning conditions.

From limited data obtained on early segments of the runs in 1944, 1945, and 1946, it is estimated that the run of steelhead past Lewiston averages at least 10,000 fish annually. No data are available on the sizes of steelhead runs in other streams of the Trinity River drainage.

Steelhead spawning begins in the upper Trinity River during the last part of February and reaches a peak about the first of April, continuing scattered into June. Adult steelhead, which do not necessarily die after spawning, start a return migration to the ocean after spawning is completed. Young steelhead start emerging from the gravel in late April. The bulk of young steelhead do not move toward the ocean until they are at least one year old.

Resident rainbow trout are distributed in fairly large numbers throughout the drainage. Brown trout are also well distributed but are fewer in number and more conspicuously absent from the upper extremities of the river and its tributaries than are rainbows. Definite spawning migrations of brown trout occur in the Lewiston area but the size of these runs is unknown. Populations of eastern brook trout occur in colder waters of the upper extremities of the Trinity River and its tributaries.

Shasta River: Numbers of Anadromous Fishes and Their Spawning Areas

Irrigation districts were formed in Shasta Valley in 1924, initiating large-scale irrigation. Since then, water from the several tributaries and from the main Shasta River has been used extensively for agricultural and domestic purposes. This practice, no doubt, contributed to the decline of salmon and steelhead runs in the Shasta River. Runs of king salmon in the Shasta River were very large in the past, for even in 1931, when the Shasta was considered to be in poor shape, 81,000 kings utilized the spawning beds. This may be as great a number as has ever been known to enter a similar California stream!

A fish counting rack was built on the Shasta River near its confluence with the Klamath River in 1930 by the California Department of Fish and Game. This rack was moved upstream six miles in 1938, and from then on an unknown number of salmon has spawned in the river below. In 1937 it was demonstrated that about one-third of the total Shasta River king salmon run spawned in the six-mile gorge section of the river below the counting rack. The number of fish spawning below the racks no doubt varies from year to year; however, by adding one-third to the run in years since 1937, the totals will probably be reasonably close to the true figure for the entire Shasta River. Table 3 shows actual fish counts on the Shasta River from 1930 to 1955. During this period the average annual run of king salmon counted in the Shasta River was a little over 20,000.

Partial counts of silver salmon and steelhead, in addition to the king salmon count, were kept in the winters of 1948-49 through 1955, but in most previous years counts were of king salmon alone. These counts are also shown in Table D-3.

TABLE D-3

COUNTS OF SALMON AND STEELHEAD AT SHASTA RACKS, SHASTA RIVER

Year	Period of count	King salmon	Silver salmon	Steelhead
1930	----------	19,338		
1931	----------	81,844		
1932	Sept. 19-Dec. 10, 1932	34,689	----------	*8,513
1933	----------	11,570		
1934	----------	48,668		
1935	----------	74,537		
1936	----------	46,115		
1937	----------	33,255		
1938	----------	**9,090		
1939	----------	28,169		
1940	----------	55,155		
1941	----------	13,252		
1942	----------	11,425		
1943	----------	10,022		
1944	----------	11,498		
1945	----------	18,181		
1946	----------	7,590		
1947	----------	341		
1948	Aug. 30, 1948-April 13, 1949	37	372	3,957
1949	Sept. 15, 1949-Jan. 19, 1950	139	312	*491
1950	Sept. 1-Oct. 30, 1950	*248		
1951	Aug. 2-Oct. 30, 1951	2,036	*160	*110
1952	Aug. 27-Oct. 31, 1952	1,666	*16	*103
1953	Aug. 31-Oct. 30, 1953	1,605	*22	*128
1954	Aug. 31-Oct. 29, 1954	2,624	*2	*112
1955	Aug. 24-Nov. 8, 1955	1,807	*43	*77

* Incomplete count.

** Rack moved from mouth to six miles upstream in 1938. Since 1938 numbers of king salmon spawning below rack estimated to be one-third of numbers passing rack.

Importance of Sport Fishing

Postal card surveys conducted by the California Department of Fish and Game give valuable information concerning trends in angling pressure and angling success for important sport fisheries in California. During 1955, a questionnaire form was sent to a selected number of anglers and much valuable information was obtained. Although in most cases results are based on a limited number of respondents and are subject to considerable error, they yield the best information available at this time.

It was estimated that approximately 368,000 angler-days were expended during 1955 in Siskiyou and Trinity Counties to catch an estimated 2,477,000 trout. Trout fishermen average 11 days annually in pursuit of trout. It is therefore estimated that approximately 33,500 anglers participated in the taking of trout in Trinity and Siskiyou Counties during 1955.

Results of the survey indicate that approximately 60,000 steelhead were taken by anglers in Trinity and Siskiyou Counties in 1955. Many steelhead in addition to these were taken in the lower Trinity and Klamath Rivers in Humboldt and Del Norte Counties, but the extent of this catch is not known. A preliminary estimate of 40,000 steelhead caught in the section of the drainage seems not unreasonable. Assuming the steelhead catch to be 100,000 fish, and using the statewide average of 8.4 steelhead per successful angler per season, it is estimated that approximately 12,000 anglers participated in the steelhead catch from this drainage in 1955. Using the statewide average of 5.8 as the number of days fished by each steelhead angler, approximately 69,000 angler-days were expended in the Klamath drainage in 1955.

The 1955 survey listed the sport salmon catch in inland waters according to river system instead of by county; therefore, a more truly representative figure was obtained. It was estimated that 72,500 salmon were landed in the Klamath River and 22,500 salmon landed in the Trinity River, for a total of 95,000 salmon in the Klamath drainage. A creel check conducted in the Klamath River estuary indicated 10,500 fish landed with 3.2 man-days expended for each fish caught. Using the same success ratio for the entire drainage, approximately 304,000 angler-days were expended on salmon fishing in 1955.

Anglers, and hunters also, seeking fish and game in the Klamath River Basin come from all sections of California and also from other states. A study conducted near the mouth of the Klamath River in 1951 revealed that the anglers were residents of 48 different California counties. Los Angeles County was the leader in anglers represented, claiming 55 per cent of the total fishermen. There were also anglers from Oregon, New Mexico, Texas, Arizona, Washington, and Florida. A year-long study in 1949 and 1950 on the Klamath River between Copco Dam and the mouth of the Salmon River produced similar results. In this upper river section 41 per cent of the anglers were from 43 California counties and 4 per cent were from 8 different states including Hawaii. The remaining anglers were from nearby communities.

Importance of Ocean Commercial Salmon Fishing and Ocean Sport Salmon Fishing

The average annual spawning run of king salmon in the Klamath River system is estimated to be at least 109,000 fish. This figure is based on actual counts of fish passing weirs on the Shasta and Klamath Rivers; a tagging study on the upper Trinity River; and estimates of annual runs in other streams based on observations of biologists of the California Department of Fish and Game and the U. S. Fish and Wildlife Service. No estimates are available concerning the size of silver salmon runs in the drainage as a whole and only scattered data are available on individual streams. Table D-4 shows the average annual sizes of king salmon runs in principal streams of the Klamath drainage, along with the method used to obtain these figures.

Fish marking and tagging experiments have shown that Klamath River king salmon are caught by commercial fishermen at sea along the California coast as far south as Monterey and as far north as the coasts of Oregon and Washington. This would also hold true for sport fishermen catches at sea. Thus, aside from supporting a valuable inland sport fishery, Klamath River salmon also contribute to a commercial as well as a sport fishery at sea.

On the basis of a 2:1 spawning escapement (two salmon taken by fishermen at sea for each one returning to spawn), approximately 218,000 salmon which were reared in the Klamath River Basin are taken by commercial and sport fishermen in the ocean each year. Records of sport and commercial salmon landings in California's ocean waters during 1955 show that approximately 1,118,000 salmon were taken by both sport and commercial fishermen. One hundred and ninety-seven thousand salmon, or 18 per cent, were landed by sport fishermen and 921,000 salmon

TABLE D-4

ESTIMATED NUMBER OF KING SALMON SPAWNING ANNUALLY IN THE KLAMATH RIVER DRAINAGE

Stream	Number of king salmon	How count was obtained
Shasta River	20,000	Average of weir counts 1930 through 1955
Trinity River (above South Fork)	40,000	Tagging study in 1955 and 1956
Salmon River	2,000	Estimate
Scott River	5,000	Estimate
Klamath River at Klamathon	12,000	Average of weir counts 1925 through 1955
All other tributaries	10,000	Estimate
Total annual run	109,000	

(11,977,697 pounds at 13 pounds per salmon), or 82 per cent were landed by commercial fishermen. Of the 218,000 salmon contributed to ocean fishermen by the Klamath River system each year, approximately 39,000 are caught by anglers and 179,000 are landed by commercial fishermen, based on the ratio of sport to commercial salmon landings of ocean caught fish in 1955.

The retail value of the 179,000 salmon taken by commercial fishermen is estimated to be $1,303,000 based on a retail price of 70 cents a pound and an average weight of 13 pounds for each fish landed, minus 20 per cent of the weight landed for cleaning losses.

Water Requirements for Fish

The value of water for fisheries, wildlife, and recreational purposes should be carefully considered in planning water resource developments. Every effort should be made to expand and not merely attempt to preserve fish life and recreational values which might be adversely affected by the construction of water projects. Water resource development is essential to the economy of the State, but much resulting damage to fish and game can be minimized or eliminated with proper planning.

Stream flow estimates to maintain fish populations near their present levels are presented for several streams in the Klamath drainage in Tables D-5 through D-7. Streams so selected are the larger ones in the watershed—the ones most likely to be subjected to studies by those planning water projects. It does not follow that streams not included in these tables are unimportant and that there are not water requirements for fish and game in them. Existing fish populations could be maintained with the flows presented but in most instances more water would be required to increase populations, probably in conjunction with other habitat improvement. These stream flows should be relatively stable for maximum fish production.

TABLE D-5

ESTIMATED MINIMUM STREAM FLOWS TO MAINTAIN GAME FISH POPULATIONS NEAR THEIR PRESENT LEVELS AT SELECTED POINTS ON THE KLAMATH RIVER

Stream	Area	Minimum flow April-Sept. (cfs.)	Minimum flow Oct.-Mar. (cfs.)
Klamath River	At Klamath	1,200	2,000
Klamath River	Above confluence with Trinity River	650	1,200
Klamath River	Above confluence with Salmon River	500	1,000
Klamath River	Above confluence with Scott River	500	1,000
Klamath River	At Confluence with Shasta River		
	Without daily fluctuation	1,000	1,000
	With daily fluctuation (high)	1,500	1,500
	(low)	500	500

TABLE D-6

ESTIMATED MINIMUM STREAM FLOWS TO MAINTAIN GAME FISH POPULATIONS NEAR THEIR PRESENT LEVELS ON FOUR KLAMATH RIVER TRIBUTARIES

Stream	Area	Minimum flow April-Sept. (cfs.)	Minimum flow Oct.-Mar. (cfs.)
Salmon River	At confluence with Klamath River	150	300
Scott River	At confluence with Klamath River	100	250
Shasta River	At confluence with Klamath River	50	200
Trinity River	At confluence with Klamath River	250	1,000

TABLE D-7

MINIMUM STREAM FLOWS TO BE RELEASED TO MAINTAIN GAME FISH POPULATIONS NEAR THEIR PRESENT LEVELS IN THE TRINITY RIVER BELOW LEWISTON

Dates (all dates incl.)	Minimum flow (cfs.)
October 1-October 31	200
November 1-November 30	250
December 1-December 31	200
January 1-September 30	150

Widely fluctuating flows, such as those below power plants that are utilized for peaking purposes without reregulation, would have a fish carrying capacity approximately equal to the lowest flow of the cycle.

Increasing Fish Spawning Areas

Many dams were built in the Klamath River drainage in Trinity and Siskiyou Counties during the past 80 or 90 years for the purpose of diverting water for domestic and mining uses. All of these dams formed partial or complete obstructions to migrating fishes on their spawning runs. Some of them blocked salmon and steelhead from miles of spawning gravels farther upstream, thus confining the fish to the stream sections below the dams. Over a period of years, sizes of fish runs in these streams where dams formed complete blocks were reduced to numbers consistent with the available spawning area. The California Department of Fish and Game began removing known abandoned dams about 30 years ago. This program has recently been stepped up, and in the past few years 22 dams have been removed in the Klamath River system in Trinity and Siskiyou Counties. These removals, plus two dams in Siskiyou County which recently washed out, have made at least 210 miles of additional spawning gravel available to steelhead and salmon. Access to this additional spawning gravel will result in a gradual increase in fish populations.

HUNTING

Big Game Animals of the Klamath River System

Rocky Mountain mule deer and Columbian black-tailed deer are the principal big game animals in

the area. Deer migrations are the rule rather than the exception for this drainage. The interstate deer herd, which exists within the confines, spends winters in California and summers in Oregon. The north-south migration route lies primarily east of Clear Lake in Modoc County. However, some deer migrate from Oregon to California by the west side of Clear Lake. Deer inhabiting the summer range of Glass Mountain also move into this "Devil's Garden" winter range. The deer migration pattern along the Klamath River, below Copco, is one of dropping from higher areas to the flats beside the Klamath and tributary streams. This is particularly noticeable near Copco, Hamburg, and Scott Valley. These patterns can be seen more clearly on the accompanying map (Plate 1), which covers all of the area except the Upper Klamath. Black-tailed deer migration patterns along the coast are not as clearly defined as are the migrations of mule deer in the eastern portion of the drainage area.

Stream-side deer winter ranges are, for the most part, very limited in area. Any reduction in width of these ribbon-like ranges by the creation of large water impoundments could easily bring about a serious problem of deer food scarcity. This refers, of course, to areas of significant snow precipitation and where dense timber stands grow almost to water's edge. A dense timber type is not a producer of deer browse until logged off.

Other big game species in the Klamath River drainage area are pronghorn antelope and black bear. Antelope are hunted only when a population increase provides the necessary surplus. The two most important bands are those inhabiting the area south of Clear Lake and around Mt. Dome. These bands wander back and forth and may share a common wintering area just northwest of Clear Lake. North of Clear Lake the antelope range extends well into Oregon, with the bulk of the population in this range occurring along a strip averaging about 12 miles in width. The antelope population is presently at a low ebb and hunting is not permitted.

Little is known of the hunting effort expended in pursuit of black bear, but there are good numbers of these animals along the Salmon River and west of Hamburg along the Klamath River. Humboldt County is the number one bear county in the State, while Trinity County usually ranks second in numbers of bear bagged. It is estimated that between 15 and 20 per cent of the reported 4,600 bears taken in California during 1955 were bagged in the Klamath River drainage.

Importance of Big Game

The deer population of the Klamath River drainage was estimated to be 128,000 between 1947 and 1949. There is no reason to believe that this figure has changed significantly either up or down to the present time, as ranges have been well stocked with deer for the past 10 years.

During the 1955 deer hunting season, the Klamath River Basin produced 11 per cent of the statewide deer kill, or about 7,750 deer. More than three-quarters of the deer kill in Siskiyou County and most of the deer kill in Trinity County was made in those portions contributing to the drainage of the Klamath River. The average annual take for the period 1948-1952 was slightly in excess of 4,000 antlered deer. This increased to about 5,750 in 1955, with an additional 2,008 antlerless deer taken during a special shoot held in the Devil's Garden area of Modoc County. This area is within the Klamath River drainage.

The Klamath River drainage supports very heavy deer hunting pressure. Hunters from all parts of California swarm into this area each fall in pursuit of deer. Many hunters consider it one of the few areas in the State where they stand a chance of bagging a trophy buck.

During 1955, 410,205 licensed hunters in California bagged 71,126 legal deer. This amounted to one successful hunter in six. If 11 per cent of the State's deer kill was made in the Klamath River Basin, then approximately 11 per cent of the State's licensed hunters, or 45,000, probably participated. Using an average of seven man-days per hunter, it is estimated that approximately 315,000 hunter-days were expended in the deer kill in this basin in 1955.

Upland Game Birds and Mammals of the Klamath River System

Representatives of all of California's upland game families occur in the Klamath River Basin.

Several species of upland game birds inhabit the Klamath River drainage area. Coast California quail are found in the humid lower portiou of the Klamath Basin from the vicinity of Orleans on the Klamath River and Salyer on the Trinity River westward to the Pacific Ocean. The valley California quail's range begins at the eastern end of the coast California quail's range, where the two races intergrade, and extends eastward throughout the Klamath Basin in all areas suitable to the bird's requirements. The type of territory inhabited is much more arid than that of the coast bird, being primarily chaparral in broken patches, as well as riparian willow situations. The coast mountain quail inhabits about the same general area as the coast California quail, but its distribution extends a little farther inland up the Klamath River to the vicinity of Seiad Valley and South Fork Mountain in Trinity County. Its range locally, however, is quite different since it primarily inhabits mountain-side brushland, often in continuous unbroken belts. The Sierran mountain quail intergrades with the coast form along the eastern border of the latter's

range. It extends eastward in suitable habitat throughout the entire Klamath drainage. Chukar partridges and ring-necked pheasants are found principally in the Tule Lake-Lower Klamath Area. Chukars are also distributed on the western side of Shasta Valley and between this valley and Scott Valley, while pheasants are found in fair numbers in Shasta Valley and in lesser numbers in Scott Valley. Three species of grouse, including the Oregon and Sierra sooty grouse and the Oregon ruffed grouse are also found in sections of the Klamath River drainage while the sage hen's range reaches into the eastern edge of the Klamath Basin in Modoc and eastern Siskiyou counties. Band-tailed pigeons are found along the entire length of the Trinity River, and along the Klamath River from the sea to Hornbrook, as well as in all of the Klamath River's tributary drainage areas west of Shasta Valley and the Goose Nest Range on the east side of Shasta Valley. The mourning dove is found throughout the Klamath River Basin except in the humid coastal timber and in the higher mountains to the east. Table D-8 includes a list of upland game species and the types of habitat each occupies within the Klamath River drainage area in California.

Several species of upland game mammals are also represented in the Klamath Basin. The California gray squirrel is found in the pine and oak belts throughout the Klamath drainage, principally east of the Coastal redwood belt. Nuttall cottontail rabbits are found from Shasta Valley eastward, while pigmy rabbits and white-tailed jack rabbits are limited to the extreme portion of the basin just reaching the area on the northwestern corner of Devil's Garden in Modoc County. Of the two black-tailed jack rabbits found along the Klamath, the California black-tailed jack rabbit is distributed from Shasta Valley westward, while the Washington black-tailed jack rabbit is found east of Shasta Valley. Oregon snowshoe rabbits inhabit a narrow area east of the more humid coastal belt, including most of the brush and timber country in Trinity and western Siskiyou Counties, from the western site of Butte Valley westward throughout most of the Marble and Siskiyou mountains east of the Happy Camp-Waldo road. Redwoods brush rabbits are found in a narrow strip along the coast and do not extend their range eastward past Happy Camp on the Klamath River.

Importance of Upland Game

According to the 1955 postal card survey made by the California Department of Fish and Game, 1.7 per cent of the State pheasant kill was bagged that year in Siskiyou County. Most of these birds were taken in the Klamath River drainage. Jack rabbits, cottontail rabbits, brush rabbits, and tree squirrels were the most sought after upland game mammals, with approximately 17,800 of these game animals being taken in Siskiyou and Trinity Counties in 1955. Quail, pheasants, doves, and pigeons contribute greatly to the hunter's bag of upland game birds. Table 9 gives estimates of the number of upland game birds and mammals taken in Siskiyou and Trinity Counties in 1955, based on the Department of Fish and Game postal card survey.

In 1955 there were 634,107 licensed hunters in California. It is estimated that 80 per cent of the total licensees, or 507,286 hunters, participated in the harvest of 6,405,800 upland game birds and mammals in California during 1955, including 59,700 in Siskiyou

TABLE D-8

KLAMATH BASIN UPLAND GAME HABITAT

Upland game	Humid coast	Interior coniferous timber	Interior chaparral and oak	Open slopes and valleys	Riparian willows alders	Sagebrush juniper
Birds						
Coast California quail	x			x	x	
Valley California quail			x	x	x	x
Coast Mountain quail	x		x			
Sierran Mountain quail		x	x			x
Chukar partridge				x		x
Oregon sooty grouse	x					
Sierra sooty grouse		x				
Oregon ruffed grouse	x				x	
Sage hen						x
Ring-necked peasant				x		
Band-tailed pigeon	x	x	x		x	
Mourning dove	x		x	x	x	x
Mammals						
California gray squirrel		x				
Nuttall cottontail			x	x		x
Pigmy rabbit						x
Redwoods brush rabbit	x				x	
White-tailed jack rabbit						x
California black-tailed jack rabbit	x		x	x		
Washington black-taded jack rabbit			x	x		x
Oregon snowshoe rabbit		x	x		x	

TABLE D-9

ESTIMATED UPLAND GAME TAKE IN SISKIYOU AND TRINITY COUNTIES IN 1955

Species	Trinity County	Siskiyou County	Total
Quail	8,500	7,300	15,800
Doves	1,000	9,700	10,700
Pigeons	2,700	1,200	3,900
Brush and cottontail rabbits	1,400	2,800	4,200
Jack rabbits	1,800	3,400	5,200
Pheasants	----	11,500	11,500
Tree squirrels	7,700	700	8,400
TOTALS	23,100	36,600	59,700

and Trinity Counties. These figures include pheasants, quail, doves, pigeons, Chukar partridges, sage hens, brush and cottontail rabbits, jack rabbits, and tree squirrels. On the basis of statewide average figures, 4,728 hunters were necessary to take the estimated 59,700 upland game animals killed in Siskiyou and Trinity Counties in 1955. Using an average of 8.5 days per hunter, it is estimated that about 40,000 man-days were expended on upland game species.

Water Requirements for Big Game and Upland Game

Even though the total amount of water required for maintenance of game species in the Klamath drainage is small compared with that of other beneficial uses, a definite requirement is present. The needs of game species, exclusive of waterfowl, are best expressed in the form of small quantities measured in gallons rather than acre-feet. The supply, however, must be widespread and scattered over the range of these animals in proper relation to basic food and cover sources. Eight gallons of water a day for each square mile, if distributed on the basis of 800 gallons located on one section, leaving 99 sections dry, would be of little use to game. Ideally, where, populations of small game species are present, there should be available water for every quarter section or at least for every section in drier areas. Areas of high potential game populations, that abound in cover and desirable foods, have higher water needs than do areas of low game productivity. Within the generality above, areas that are desert or semi-desert in climate have higher needs for free water than do coastal areas. Table D-10 lists the estimated minimum daily water requirements in Siskiyou and Trinity Counties for upland game and big game animals. Table D-11 includes a list of upland game species and their normal watering places in the Klamath Basin.

Migratory Waterfowl: Importance of Klamath Basin

The United States Fish and Wildlife Service is cooperating with the states, including California, in formulating a waterfowl management program for the Pacific Flyway which is based on provision of a system of properly located refuge areas sufficient to meet the needs of the birds and to prevent excessive crop depredations.

The two Klamath Basin refuges, Tule Lake and Lower Klamath National Wildlife Refuges, are used almost year-long by waterfowl and are the key to the

TABLE D-10

ESTIMATED MINIMUM DAILY BIG GAME AND UPLAND GAME DRINKING WATER REQUIREMENTS IN SISKIYOU AND TRINITY COUNTIES

	Area, in square miles	Average gallons per square mile	Total gallons per county
Siskiyou	6,078	22	133,716
Trinity	3,276	8	26,208
TOTAL			159,924

TABLE D-11

NORMAL WATERING PLACES OF UPLAND GAME IN THE KLAMATH BASIN

Upland game	Rivers	Canyon bottoms	Small streams	Flatland water	Upland springs	Mineral springs
Birds						
Coast California quail	x	x	x	x	x	
Valley California quail	x	x	x	x	x	x
Coast mountain quail	x	x	x		x	
Sierran mountain quail	x	x	x		x	x
Chukar partridge		x	x		x	
Oregon sooty grouse	x	x	x		x	
Sierra sooty grouse		x	x		x	
Oregon ruffed grouse	x	x	x			
Sage hen			x	x	x	
Ring-necked pheasant				x		
Band-tailed pigeon	x	x	x		x	x
Mourning dove	x		x	x	x	x
Mammals						
California gray squirrel	x	x	x		x	x
Nuttall cottontail			x	x	x	x
Pigmy rabbit				x	x	
Redwoods brush rabbit	x	x	x		x	
White-tailed jack rabbit			x	x	x	
California black-tailed jack rabbit		x	x	x	x	
Washington black-tailed jack rabbit			x	x	x	x
Oregon snowshoe rabbit	x	x			x	

management plan. The bulk of this use is during the fall migration, which begins in late July and usually ends in early December. During this period the numbers of waterfowl on the refuges vary considerably. There are usually about 175,000 in late July, 1,000,000 in late August, 2,500,000 in late September, 4,000,000 in October, and 1,500,000 in late November. The number during all of October and early November usually levels off at over 4,000,000 birds. The Tule Lake-Lower Klamath waterfowl areas are also quite important as nesting habitat, and over 75,000 young birds are produced here each summer.

The Klamath Basin is the best location along the Pacific Flyway to provide a waterfowl stopover. It is attractive, effective, and with maximum opportunity to control local depredations while delaying the waterfowl migration enough to be of substantial benefit in reducing damage to Central Valley crops.

In addition to being essential to the maintenance of Pacific Flyway populations of waterfowl, the Tule Lake-Lower Klamath waterfowl areas are absolutely essential to maximum crop production in the Central Valley. There is no stopping place for ducks between this area and the Central Valley that is capable of holding more than a handful of birds. Should the carrying capacity for the millions of ducks that stop over in this area in the fall be jeopardized, losses to rice farmers and permanent pasture growers particularly, as well as other agriculturalists in the Central Valley, would be considerable.

Importance of Migratory Waterfowl

The 1955 postal card survey by the California Department of Fish and Game indicated that 135,800 ducks, 4.1 per cent of the State's duck kill, and 62,600 geese, 18.5 per cent of the State's goose kill, were taken in Siskiyou County. Tule Lake and Lower Klamath refuges are located in Siskiyou County and most of the ducks and geese bagged in this county are taken in the Klamath Basin. The statewide average bag of ducks and geese combined, for hunters using state-owned areas, was 2.8 birds per hunter-day. Assuming that this degree of success also holds true for hunters outside the areas, 71,000 hunter-days were expended in the take of 198,400 ducks and geese in Siskiyou County in 1955.

Very few migratory waterfowl are bagged in the Klamath Basin in California outside of Siskiyou County. It is estimated from the Department of Fish and Game postal card survey that only 1,400 ducks were bagged in Trinity County in 1955.

Water Requirements for Migratory Waterfowl

The Fish and Wildlife Service does not plan any new waterfowl management refuges in the Klamath Basin, but it does plan to expand both the acreage and water use of both present refuges. Table D-12 gives a summary of available data concerning present

TABLE D-12

PRESENT AND ULTIMATE SEASONAL WATER REQUIREMENTS FOR WATERFOWL AT NATIONAL WILDLIFE REFUGES IN THE KLAMATH RIVER BASIN IN CALIFORNIA

	Lower Klamath National Wildlife Refuge		Tule Lake National Wildlife Refuge	
Usage	Acres watered	Consumptive use in acre-feet	Acres watered	Consumptive use in acre-feet
Present	16,600	80,600	13,200	78,000
Estimated probable ultimate	30,000	94,000	32,200	91,000

and probable ultimate water requirements for migratory waterfowl at government-operated refuges in the Klamath River Basin.

The California Department of Fish and Game maintains no migratory waterfowl management areas or refuges within the basin, nor are any anticipated in the future. No data are available concerning water requirements for private gun clubs in the area.

TRAPPING

Fur Animals of the Klamath River System

Principal fur bearing animals in the Klamath River Basin, with regard to numbers taken and cash returns to trappers, are muskrat and mink. Other fur bearers, including river otter, fisher, marten, coyote, bobcat, ringtail cat, badger, skunk, grey and red fox, and raccoon are also present and increase in importance from time to time depending upon market demands for the various types of furs.

Muskrats are now the most important fur animals taken in the Klamath River drainage area. Commencing with the original plant of 20 pairs of muskrats in Tule Lake and Shasta Valley in 1930, the entire drainage was opened to their colonization and it was only a few short years until compulsory reports from licensed trappers revealed, as early as 1940, that an annual catch of over 38,000 "rats" was made in Siskiyou County alone. Klamath River from Copco Dam downstream contains very little suitable muskrat habitat, but the upper drainage and its adjacent sloughs, swamps, lakes, and waterways, is one of the leading producers of muskrat in California.

Although muskrat is the most valuable fur animal in the Basin, considering gross returns to the trapper, other water-loving fur bearers including mink and otter are also quite important, their pelts from this region being of exceptionally high quality.

Importance of Fur Animals

Each trapper in California is required by law to fill out and return to the Department of Fish and

Game at the end of each trapping season a record of activities, including the number of fur animals caught and the prices received for the furs. During the 1955-56 season 912 trapping licenses were sold in California. The fur buyer's demand was for short-haired fur species such as muskrat, mink, beaver, and river otter. Long-haired types, including coyotes, badgers, skunks, raccoons, etc., sold for comparatively low prices. The estimated total value to the trappers of the entire 1955-56 fur catch in California was $100,168—a decrease of 31 per cent from the 1954-55 season. The main reason for this decrease was the occurrence of flood conditions during the trapping season.

During the 18 years of available record between 1938-39 and 1955-56, Siskiyou and Trinity Counties have produced an average of 20,939 furs annually, or over 25 per cent of the total California fur catch. Siskiyou County is by far the larger producer of the two counties. Approximately 96 per cent of the average annual catch in Siskiyou County is muskrat, while in Trinity County almost 20 per cent of the catch consists of highly prized mink. Table D-13 shows the fur catch in Siskiyou and Trinity Counties based on licensed trapper reports, compared with the total state catch for the trapping seasons of 1938-39 to 1955-56, inclusive.

During the 1955-56 season there were 71 licensed trappers in Siskiyou and Trinity Counties. The value to the trappers of the 15,030 furs of all types taken in these two counties during the 1955-56 season was approximately $15,870. The retail value of this fur catch is, of course, many times greater. Table D-14 gives a breakdown of the 1955-56 fur catch in Siskiyou and Trinity Counties and the value of this catch to the trappers.

TABLE D-13

FUR CATCH IN SISKIYOU AND TRINITY COUNTIES COMPARED WITH THE TOTAL CALIFORNIA FUR CATCH, 1938-39 THROUGH 1955-56

Year	Siskiyou County		Trinity County		California
	Total furs	Number of muskrats	Total furs	Number of mink	Total catch
1938-39	12,689	12,305	356	88	60,235
1939-40	38,772	38,239	991	116	101,874
1940-41	34,553	33,703	538	91	108,720
1941-42	28,643	27,641	804	93	112,789
1942-43	40,922	40,520	436	35	86,593
1943-44	28,982	27,962	788	80	88,668
1944-45	32,895	31,704	1,221	170	83,552
1945-46	15,659	14,249	818	125	74,169
1946-47	13,606	12,063	622	211	64,859
1947-48	14,741	13,486	350	35	59,871
1948-49	6,225	5,589	317	101	58,383
1949-50	5,872	5,458	151	56	47,190
1950-51	8,118	7,638	351	92	59,081
1951-52	13,434	12,807	345	128	80,382
1952-53	10,720	10,194	176	32	91,266
1953-54	21,835	21,437	234	88	107,435
1954-55	25,241	24,386	282	141	112,409
1955-56	14,830	14,461	200	103	87,581
TOTALS	367,915	353,824	8,980	1,785	1,485,057
Yearly average	20,440	19,657	499	99	82,503

RECREATION

Recreational Use of National Forests

Klamath, Shasta-Trinity, and Six Rivers National Forests, all or parts of which are located within the Klamath River drainage area in California, provide numerous camp sites, picnic grounds, wilderness trails, etc., for those seeking outdoor recreation. Estimates of the recreational use of these national forests, including 15 separate recreational activities, are made annually by the United States Forest Service. In 1955, Forest Service records indicate that 98,363 people spent 366,289 recreational-use days (man-days) in national forests within the Klamath River drainage areas of California. These figures do not include people who used recreational facilities provided by private resorts, motels, private camp grounds and private trailer units, etc., in national forests; nor in the basin outside national forest boundaries. There are gaps in the recreational-use figures presented here for the lower Trinity River from Hoopa to Weitchpec and along the lower Klamath River from Weitchpec to the ocean, as well as most of Scott and Shasta Valleys and other sections of the upper Klamath drainage not included in national forests. Table D-15 shows the estimated recreational use of public facilities within the national forests involved during 1955. Included are the numbers of people participating in such activities as hunting, fishing, camping, picnicking, swimming, organization camping, wilderness travel, general enjoyment and sightseeing, gathering forest products for pleasure, scientific study and hobbies, and other activities. It is of significance to note that

TABLE D-14

VALUE TO THE TRAPPER OF THE 1955-56 FUR CATCH IN SISKIYOU AND TRINITY COUNTIES

Fur bearer	Number caught in Siskiyou County	Number caught in Trinity County	Average price to trapper	Total value
Beaver	5	0	$9.20	$46.00
Bobcat	40	6	1.72	79.00
Coyote	86	3	2.93	261.57
Feral cat	17	0	----------	----------
Grey fox	1	8	0.23	2.04
Mink	107	103	15.91	3,342.80
Muskrat	14,461	0	0.82	11,858.02
Raccoon	86	47	0.95	126.89
Ringtail cat	3	15	1.13	20.34
River otter	3	6	12.50	112.50
Spotted skunk	12	4	0.45	7.16
Striped skunk	7	8	0.88	13.23
Weasel	2	0	0.29	0.58
TOTALS	14,830	200		$15,870.23

TABLE D-15

ESTIMATED RECREATIONAL USE OF PUBLIC FACILITIES IN NATIONAL FORESTS LOCATED IN THE KLAMATH RIVER DRAINAGE AREA IN CALIFORNIA DURING 1955

National Forest	Number of visitors	Number of recreational use days (man-days)	Number of hunters and fishermen
Klamath	52,245	170,467	34,810
Shasta-Trinity	26,175	132,000	19,834
Six Rivers	17,943	63,822	5,475
TOTALS	98,363	366,289	60,119

over 60 per cent of the people using United States Forest Service facilities in this area indicated the primary purpose of their visit was to go hunting or fishing.

Importance of Recreation

During 1955 an estimated 38,250 people, exclusive of hunters and fishermen, spent approximately 77,200 recreational-use days (man-days) on national forest lands encompassed by the Klamath River drainage area in California. These were only the people using the public facilities, as no records are available concerning the recreational use of private resorts, motels, trailer parks, etc.

WATER DEVELOPMENT PLANS

By virtue of abundant water supplies the Klamath River Basin will play an important part in the future development of California's water resources. Plans have been developed for exporting large quantities of surplus Klamath River water to deficient areas in central and southern California, and plans are presented in this bulletin for the development of water to satisfy requirements within the basin. All water projects proposed would have definite effects upon fisheries and wildlife resources, and upon outdoor recreational facilities as well. These projects are shown on Plate 16 of this bulletin. Studies of these resources, and of the effects of the proposed developments upon them, must necessarily be a part of further investigation of the proposed projects if fishing, wildlife, and recreational values involved are to be developed and maintained. Only through such integrated planning can damage to these resources be minimized or eliminated and benefits to them developed to the maximum possible extent.

Large-scale development of water resources in the Klamath River Basin has been limited when compared with other portions of California. The Copco Dams, constructed on the Klamath River by the California Oregon Power Company in the early 1920's, and Shasta River Dam (Lake Dwinnell), constructed on Shasta River in 1926 by the Montague Water Conservation District, represent the only major developments existing in the California portion of the Klamath River Basin at the present time. Trinity Dam and diversion, currently under construction by the Bureau of Reclamation will, when completed, be the largest water project in the basin.

Both the Copco Dams and Dwinnell Reservoir have had detrimental effects upon fisheries resources in the Klamath River Basin. In the case of the Copco Dams, all upstream migration of salmon and steelhead beyond Copco Dam Number 2 was stopped when the project was constructed. Of greater detriment to fisheries have been the fluctuating flows released from Copco Dam Number 2 Power Plant. Water releases from the power plant correspond to the amount of power generated, the requirements for which change frequently during the course of each day. Fluctuation in water releases are especially critical in years of deficient water supply. The Department of Fish and Game attributes the drowning of 18 persons in the past eight years, and the loss of over 2,000,000 game fish each year, to fluctuating releases from the Copco Dams.

On July 27, 1959, the California Oregon Power Company and the Department of Fish and Game and the Fish and Game Commission entered into an agreement intended to solve the fluctuation problem. The agreement provides that Copco's Iron Gate development on the Klamath River will be so operated as to control, insofar as possible, fluctuations in the river.

Copco's application No. 17527 to appropriate 3,000 cubic feet per second of water annually from the Klamath River for power purposes at the Iron Gate site was protested by the Department of Water Resources. The Department stipulated with Copco on January 26, 1960, that its protest before the State Water Rights Board should be dismissed if certain conditions are included in the permit to the Company on application No. 17527. They are that the water rights granted by the permit are subordinate to other water rights from the Klamath River for use in the Shasta Valley-Ager area for higher uses, up to an annual quantity of 220,000 acre-feet. Until March 1, 2006, a maximum annual diversion amount of 120,000 acre-feet and seasonal rates of diversion applicable to such higher uses must be observed. Compensation fixed by agreement or eminent domain proceedings for use of Copco's facilities in making such uses may be required. These conditions are contained in permit No. 12259 based on application No. 17527, which was granted by the State Water Rights Board on April 12, 1960.

Detrimental effects to fisheries caused by Dwinnell Reservoir stem from a reduction in natural downstream flows in the Shasta River, particularly in the fall and early winter during salmon migration and spawning periods. Also, some spawning areas were blocked by construction of the dam.

Fisheries problems connected with the Bureau of Reclamation's Trinity Project have been studied by the Department of Fish and Game and the Fish and Wildlife Service and appear susceptible to solution. The fish protection program at this project currently includes releases of water to satisfy downstream requirements, and a salmon and steelhead hatchery below the dam. During the construction period salmon and steelhead will be trapped below the dam site and transported to upstream areas to spawn.

Agencies of the States of Oregon and California currently developing the Klamath River Compact have recognized the importance of fisheries, wildlife, and recreation in this river basin. Various drafts of the proposed compact, and hearings thereon, have made special recognition of the great importance of anadromous fishes and migrating waterfowl to the economy of the basin.

Plans to Export Water from the Klamath River Basin

Plans to develop and export large quantities of surplus water from the Klamath River Basin are described in Bulletin No. 3 of the California State Water Resources Board, entitled "Report on The California Water Plan". The envisioned development consists of a series of large dams on the Klamath and Trinity Rivers, and diversions into the Klamath Basin of water from the Smith, Mad, and Van Duzen Rivers. All export water developed in the basin and received from other basins would flow or be pumped to Burnt Ranch Reservoir, from where it would flow by tunnel through the Trinity Divide into the Sacramento Valley.

The very extensive developments proposed in the export plans for the Klamath River Basin would have profound effects upon existing fisheries, wildlife, and recreational resources. Most obvious would be the almost complete elimination of salmon and steelhead habitat in the Klamath River Basin. The Department of Fish and Game recommended in their official comments on Bulletin No. 3, "The California Water Plan", that fisheries, wildlife, and recreational problems receive thorough investigation as the various units of the Klamath River Basin export plans are studied in detail. It was pointed out that fish hatcheries and releases of satisfactory quantities of water would be required to protect anadromous fish populations. The Department specifically recommended that the upstream dams included in the plan be considered for initial construction and that subsequent construction proceed downstream in series, with the lowermost dams being the last constructed. In this manner salmon and steelhead fisheries would be maintained in the remaining unobstructed portions of streams for as long a period as possible. Moreover, technological advancements in reclaiming waste water or desalting sea water, or water requirements smaller than anticipated, might preclude the necessity of constructing the downstream features of the plan.

Table D-61 shows the reservoirs proposed in the export plan for the Klamath River Basin as described in California State Water Resources Board Bulletin No. 3.

Local Development Plans for the Klamath River Basin

The projects proposed for local development within the Klamath River Basin involve much smaller dams and reservoirs than those considered in the export plan. Their accomplishments include the provision of water for agricultural, municipal, and hydroelectric power purposes, and in some cases for the maintenance and enhancement of fisheries, wildlife, and recreation. The proposed local development reservoirs and some of their characteristics are shown in Table D-17.

Iron Gate Reservoir is proposed on the Klamath River seven miles downstream from Copco Dam to reregulate the releases from Copco Power Plant and to serve as a forebay for the Bogus Conduit, which would convey water to Shasta Valley. The reservoir would be of major value to fisheries and recreation in that it would release constant flows to the Klamath

TABLE D-16

CALIFORNIA WATER PLAN EXPORT RESERVOIRS PROPOSED IN THE KLAMATH RIVER BASIN

Stream and reservoir	Height of dam, in feet	Storage capacity, in acre-feet	Water surface area, in acres	Average annual fluctuation of water surface, in feet	Minimum pool reservations, in acre feet
Klamath River					
Hamburg	445	1,850,000	11,100	42	280,000
Happy Camp	625	4,120,000	18,200	40	632,000
Slate Creek	775	5,480,000	21,000	33	3,914,000
Humboldt	410	1,940,000	10,300	50	608,000
Trinity River					
Beaver	730	7,760,000	24,600	19	6,162,000
Burnt Ranch	355	246,000	2,170	17	210,000
Helena	575	3,050,000	16,300	38	382,000
Eltapom	420	1,260,000	6,300	47	584,000

TABLE D-17

LOCAL DEVELOPMENT RESERVOIRS PROPOSED IN THE KLAMATH RIVER BASIN

Stream and reservoir	Height of dam, in feet	Storage capacity, in acre-feet	Surface area, in acres	Average annual fluctuation, in feet	Minimum pool reservations, in acre-feet
Shasta River					
Montague	108	87,000	2,700	15	37,200
Grenada Ranch	62	22,800	1,285	29	1,400
Little Shasta River					
Table Rock	90	10,000	370	27	400
Willow Creek					
Red School	80	1,900	66	--	100
Klamath River					
Iron Gate	137	35,400	740	--	16,700
Scott River					
Callahan	276	133,000	1,469	72	4,700
Moffett Creek					
Highland	160	27,200	465	--	1,000
Salmon River					
Morehouse	575	910,000	4,690	82	269,000
Trinity River, South Fork					
Smokey Creek	190	16,800	380	--	300
Hayfork Creek					
Layman	160	21,500	490	37	1,000

River, eliminating the peaked and irregular flows that presently exist. Iron Gate Reservoir itself would be of little recreational value since it would often undergo rapid fluctuations in water surface elevation.

The Bogus Conduit, between Iron Gate and Red School Reservoirs, would be a hazard to local and migratory deer herds. The length of the conduit would be 20 miles, and throughout most of this length it would be an open canal. Its capacity would be 840 second-feet; it would be 30 feet wide and 10 feet deep; and its side slopes would be 1:1.

Experience elsewhere in California has shown that canals with side slopes steeper than 2:1 and widths greater than eight feet—the latter depending on the steepness of the sidehill slope—warrant the use of protective measures. Present practices call for the fencing of canals where deer might enter them, and the provision of bridges so that the animals might cross the canal. Tunnels or closed conduits would be preferable in areas of deer concentration or at migration route crossings.

Deer fencing should be at least seven feet high, with the lower five to six feet being six-inch wire mesh, and the top one to two feet being barbed wire strands eight inches apart. Deer crossings should be bridges of planking about six to eight feet wide, and fenced on either side so deer will not have access to the canal waters. A detailed study and field inspection of the entire Bogus Conduit route would be necessary to determine where fencing and bridges are required.

Red School Reservoir on Willow Creek would be an afterbay to the Bogus Conduit, and would receive Klamath River water pumped up from Iron Gate Reservoir. This small reservoir would undergo frequent and rapid water surface fluctuations, and would be of little recreational value.

Table Rock Reservoir on Little Shasta River, proposed to develop water for agricultural purposes, would be of some value for recreational purposes. It would fluctuate only moderately and should support a population of resident game fish.

Grenada Ranch Reservoir is proposed on Shasta River approximately three miles southeast of the town of Grenada, and a few miles downstream from the existing Dwinnell Dam. The reservoir would supply the municipal requirements of the City of Yreka and would provide irrigation water to downstream lands. The average fluctuation of Grenada Ranch Reservoir would be only 29 feet annually, which is not a severe fluctuation. The reservoir, however, is located in gently rolling land, and only a few feet of drawdown would expose large areas of the reservoir basin. For this reason it is not expected that Grenada Ranch Reservoir would be particularly desirable for recreational development and use. However, it could be expected to support a resident population of game fish.

Montague Reservoir, located at the outlet of Shasta Valley, would complete the development of the water supply of the Shasta River Basin. It would be formed by a relatively low dam, only 108 feet in height, and

its water surface fluctuation would average only 15 feet annually. The reservoir would be attractive for recreational purposes, and it should support a good population of game fish.

Montague Dam would have a detrimental effect on salmon and steelhead in that it would prevent them from reaching spawning areas in Shasta Valley. If Montague Dam were built while salmon and steelhead still had access to Shasta River the fish would suffer a large loss of spawning area. If, however, salmon and steelhead were previously blocked by dams downstream on the Klamath River, the damage would already have been done and Montague Dam would cause no further harm to these species.

As mentioned in a previous section, the California Department of Fish and Game operates a rack each year on Shasta River where counts of upstream migrant king salmon are obtained. Since 1938 this rack has been at a location very near the site of the proposed Montague Dam. Therefore, counts of king salmon passing the Shasta racks since 1938 will indicate almost exactly the numbers of these fish that would be blocked by the dam. During the last 18 years the king salmon counts have averaged almost 10,000 fish annually at the Shasta racks. In addition, an unknown number of silver salmon and steelhead pass this point on their upstream migrations, but are not counted because their migrations occur later in the winter after the racks have been removed. The portion of the Shasta River downstream from the counting racks supports about one-third as many king salmon as that above, and an unknown number of silver salmon and steelhead as well.

To protect the fish spawning downstream from Montague Dam, releases from storage amounting to 2,500 acre-feet per month would be made from October through March, and 1,200 acre-feet per month during the remainder of the year. The fish spawning upstream from the Montague Dam site would be lost unless some means were provided to protect them. Two possibilities for protecting these runs are apparent at the present time. A fish hatchery could be built below Montague Dam and fish propagated artificially, or a fishway could be built over the dam to enable fish to spawn naturally upstream. In the latter case, natural spawning areas would be greatly reduced due to inundation by Montague Reservoir and due to the presence of other dams upstream. Additional detailed study would be required to determine the feasibility of either the hatchery or fishway.

Two reservoirs are proposed in the Scott River Basin to satisfy water requirements within the basin. Callahan Reservoir would be formed by a 276 foot-high dam constructed below the confluence of the East and South Forks of the Scott River. Water would be released from it to be used for irrigation downstream, and to provide suitable minimum flows for fisheries. A quantity of 10,000 acre-feet annually from Callahan Reservoir has been reserved for stream flow maintenance. The reservoir would fluctuate through a wide range each year and would not be well-suited to recreational development and use. It would, however, undoubtedly support some fishing and recreational use.

Highland Reservoir on Moffett Creek would be utilized to meet downstream irrigation requirements in Scott Valley. It would block no major spawning areas and would have little effect on salmon and steelhead. The reservoir would fluctuate to such a degree that it would be of only minor recreational value.

Morehouse Dam on the Salmon River, approximately 15 miles above the mouth, is proposed to develop hydroelectric power. This project would be destructive to salmon and steelhead fisheries in that the dam would block many miles of spawning area. If, however, major export dams on the Klamath River downstream had already blocked the runs of these fish, Morehouse Dam would do no further harm to salmon and steelhead. The reservoir, when full, would form an attractive recreation pool. However, large fluctuation in water surface elevation would prevent its development and use as a major recreational attraction.

Layman Reservoir, on Hayfork Creek, is proposed to meet the water requirements of Hayfork Valley and would offer recreational benefits as well. A reservation of 3,600 acre-feet per year has been made for recreational purposes. This water could be used as an interim enhancement to anadromous fisheries, or to support trout fisheries if downstream dams were to block salmon and steelhead.

Smoky Creek Reservoir, well upstream on the South Fork of Trinity River, is designed primarily for recreational purposes. It would provide considerable interim enhancement to salmon and steelhead fisheries, or if these fish were blocked by downstream projects, its water could be released for stream trout fisheries or be held within the reservoir for fishing and other recreation. Smoky Creek Reservoir would provide 16,500 acre-feet per year for recreational purposes.

SUMMARY

Many of the values associated with wildlife resources in the Klamath River drainage are intangible, making an economic evaluation almost impossible. The amount of time and money that people are willing to spend enjoying the recreational activities associated with fish and game merely reflects the importance of these wildlife resources. Benefits derived from commercial fishing at sea, supported by Klamath River reared salmon, are more easily approximated since a market price is placed on the harvested product. Even then the exact contribution of Klamath River fish to the commercial salmon catch along the Pacific Coast is not known. Businesses and people benefiting from recreational use, hunting, and sport and commercial fishing, either in the Klamath River Basin or attrib-

utable to the Basin, are so greatly varied and widely distributed that a survey of considerable magnitude would be required to even approximate these values.

It is estimated that at least 1,197,000 man-days were spent hunting and fishing in the Klamath Basin during 1955. The commercial ocean catch of king salmon from the Klamath River system had a retail value of about $1,303,000 during 1955. An average of 21,000 fur bearers are caught in the Klamath Basin each season. The 1955-56 fur catch brought an estimated $15,870 return to trappers. The retail value of this catch would be many times greater. Those using United States Forest Service picnic areas and campgrounds for recreational purposes, such as hiking, swimming, camping, etc., comprised 38,250 people in 1955, who spent an estimated 77,200 man-days in the area. Table D-18 gives a summary of the estimated use by those fishing and hunting and by those using United States Forest Service campgrounds and public facilities in the Klamath drainage area of California in 1955.

TABLE D-18

SUMMARY OF ESTIMATED USE BY THOSE WHO UTILIZED THE WILDLIFE AND RECREATIONAL RESOURCES OF THE KLAMATH RIVER DRAINAGE AREA IN CALIFORNIA DURING 1955

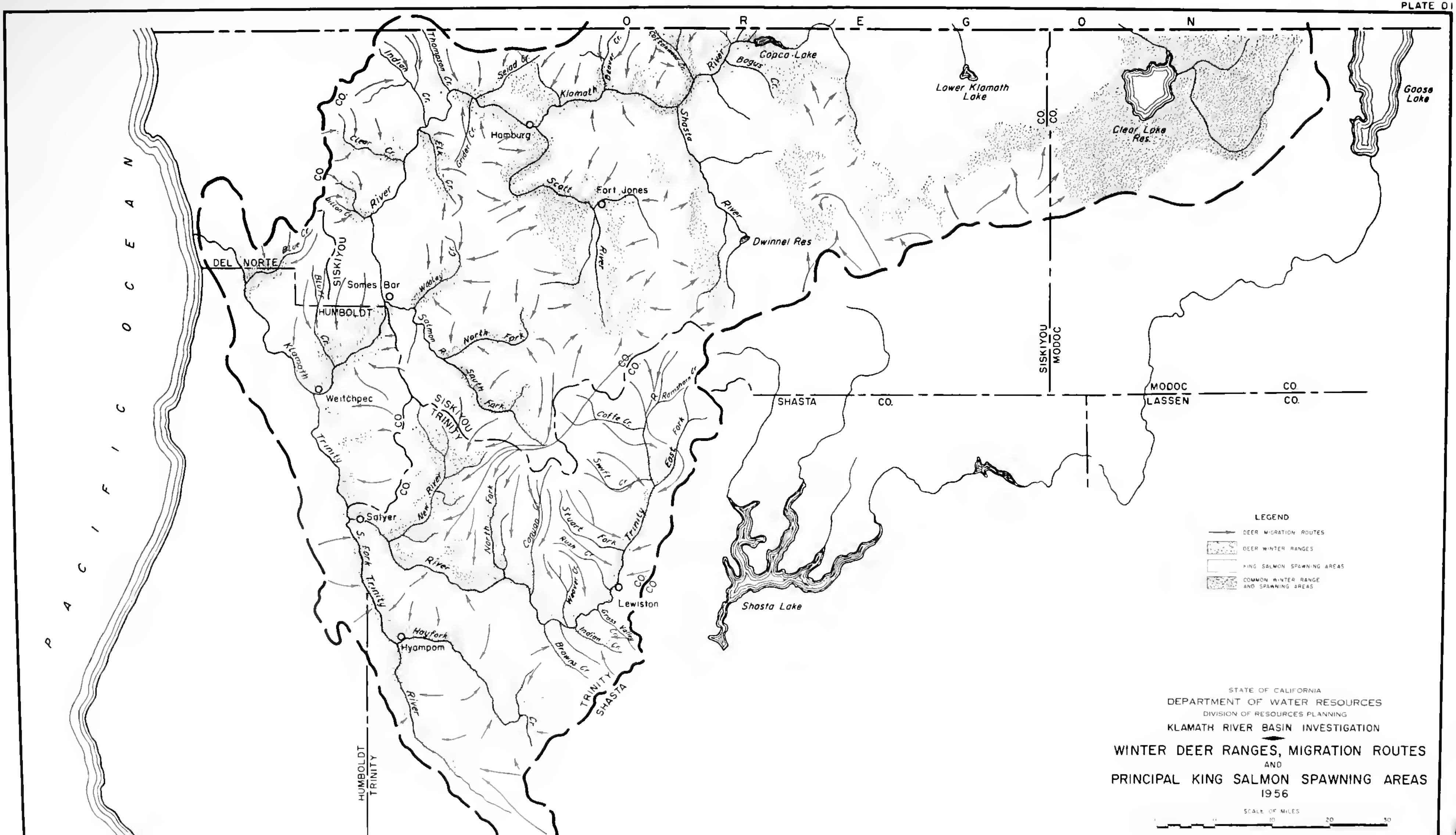
Resource	Number of man-days use	Number of fish and game taken	Commercial value
Fresh-water fishing, sport			
Trout	437,000	2,577,000	----------
Salmon	304,000	95,000	----------
Ocean fishing[1]			
Salmon, sport	30,000	39,000	----------
Salmon, commercial	----------	179,000	$1,303,000
Big game hunting			
Deer	315,000	7,750	----------
Migratory waterfowl hunting			
Ducks and geese	71,000	200,000	----------
Upland game hunting			
All species	40,000	59,700	----------
Fur trapping[2]			
All species	----------	15,030	15,870
Recreational use[3]			
Camping, picnicking, etc.	77,200	----------	----------
ANNUAL TOTALS	1,274,200	3,063,480	$1,318,870

[1] The estimated annual retail value of ocean commercial caught salmon attributable to the Klamath River Basin.
[2] Value of the commercial fur catch is based on prices paid to trappers only.
[3] Recreational use figures include the use made, exclusive of hunters and fishermen, of public facilities only, within the national forest boundaries.

Extensive plans have been made to develop the water resources of the largely undeveloped Klamath River Basin. California State Water Resources Board Bulletin No. 3, entitled "The California Water Plan," presents a plan to export over 8,000,000 acre-feet annually from the Klamath River Basin to water deficient areas in central and southern California. The effects of the proposed developments are discussed in Appendix E of Bulletin No. 3. The ultimate development of this export plan would result in the almost complete elimination of salmon and steelhead in the Klamath River Basin. During the interim period such measures as adequate water releases to stream beds and the operation of fish hatcheries would be required to maintain these valuable anadromous fisheries.

The present report is concerned primarily with local development projects in the Klamath River Basin. A total of ten reservoirs has been proposed for satisfying municipal, agricultural, hydroelectric, and recreational requirements. Insofar as recreation and fisheries are concerned, the projects would have varying effects. Salmon and steelhead fisheries would be enhanced in some instances by augmented summer flows, and by the reregulation of flows in the Klamath River below Copco Dam. These same species would likewise be threatened by the reduction of spawning areas in some cases, particularly in Shasta River. The proposed reservoirs would all be of some recreational value through boating, water skiing, swimming, etc., and could be expected to support resident populations of game fish. Fishing and aquatic recreation would be hampered in most instances by fluctuations in water surface elevation, but some recreational use would be made of the reservoirs. Montague Reservoir on Shasta River appears best suited to recreational development and use due to its comparatively stable water surface.

Facilities required to protect fisheries and wildlife include the provision of some means to preserve the salmon and steelhead that presently spawn upstream from the Montague Dam site. Further investigation would be required to determine the most feasible method of accomplishing this. Further study must also be given to the protection of deer along the Bogus Conduit.


O R E G O N
PACIFIC OCEAN
Goose Lake
Copco Lake
Lower Klamath Lake
Clear Lake Res.
Dwinnel Res
Shasta Lake
Hamburg
Fort Jones
Somes Bar
Weitchpec
Salyer
Hyampom
Lewiston
Klamath
River
Shasta
Scott
Salmon
North Fork
South Fork
Trinity
S. Fork Trinity
Hayfork
Indian Cr.
Thompson Cr.
Seiad Cr.
Beaver Cr.
Cottonwood Cr.
Bogus Cr.
Clear Cr.
Elk Cr.
Grider Cr.
Dillon Cr.
Blue Cr.
Bluff Cr.
Wooley Cr.
New River
Coffe Cr.
Ramshorn Cr.
East Fork
Swift Cr.
Stuart Fork
Rush Cr.
Weaver Cr.
Coquon Cr.
Grass Valley Cr.
Indian Cr.
Browns Cr.
DEL NORTE
SISKIYOU
HUMBOLDT
TRINITY
SHASTA
MODOC
LASSEN
CO.
LEGEND
DEER MIGRATION ROUTES
DEER WINTER RANGES
KING SALMON SPAWNING AREAS
COMMON WINTER RANGE AND SPAWNING AREAS
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
KLAMATH RIVER BASIN INVESTIGATION
WINTER DEER RANGES, MIGRATION ROUTES
AND
PRINCIPAL KING SALMON SPAWNING AREAS
1956
SCALE OF MILES
10
20
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APPENDIX E

RESERVOIR YIELD STUDIES

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TABLES

Appendix E

RESERVOIR YIELD STUDIES

TABLE E-1

SEASONAL SUMMARY OF MONTHLY YIELD STUDY, BEATTY RESERVOIR ON SPRAGUE RIVER

(In 1,000 acre-feet)

Storage capacity: 150,000 acre-feet

Seasonal yield: 110,000 acre-feet

Season	Modified inflow	Storage at end of season	Evaporation	Irrigation release	Spill
1920-21	239.6	108.4	—20.7	110.0	66.0
21-22	162.7	94.8	—20.1	110.0	46.2
22-23	122.3	86.3	—19.7	110.0	1.1
23-24	80.3	39.8	—16.8	110.0	0
24-25	158.2	69.1	—18.9	110.0	0
1925-26	89.5	32.8	—15.8	110.0	0
26-27	234.6	110.2	—21.0	110.0	26.2
27-28	161.9	85.8	—19.9	110.0	56.4
28-29	106.9	64.3	—18.1	110.0	0
29-30	99.7	37.5	—16.5	110.0	0
1930-31	75.8	10.0	—11.8	91.5	0
31-32	120.4	10.0	—13.1	107.3	0
32-33	103.4	10.0	—11.9	91.5	0
33-34	76.9	10.0	—10.8	66.1	0
34-35	124.6	10.0	—13.6	111.0	0
1935-36	147.7	31.4	—16.3	110.0	0
36-37	111.6	18.3	—14.7	110.0	0
37-38	253.7	97.1	—21.3	110.0	43.6
38-39	95.6	62.0	—19.6	110.0	1.1
39-40	164.0	78.7	—20.6	110.0	16.7
1940-41	123.7	72.6	—19.8	110.0	0
41-42	173.9	97.0	—21.1	110.0	18.4
42-43	288.1	102.2	—20.9	110.0	152.0
43-44	114.1	81.6	—20.1	110.0	4.6
44-45	149.7	97.3	—20.8	110.0	3.2
1945-46	186.3	87.1	—20.5	110.0	66.0
46-47	98.3	56.6	—18.8	110.0	0
47-48	156.6	83.5	—19.7	110.0	0
48-49	133.4	84.3	—20.4	110.0	2.2
49-50	146.4	92.3	—20.8	110.0	7.6
1950-51	201.4	88.1	—20.6	110.0	75.0
51-52	305.5	106.8	—21.0	110.0	155.8
Average seasonal	150.2		—18.3	107.4	23.2

TABLE E-2

SEASONAL SUMMARY OF MONTHLY YIELD STUDY, CHILOQUIN NARROWS RESERVOIR ON SPRAGUE RIVER

(In 1,000 acre-feet)

Storage capacity: 440,000 acre-feet

Seasonal yield: 181,200 acre-feet

Season	Historical flow of Sycan River	Accretions below Sprague and Sycan Rivers	Return flow from Beatty irrigation release	Inflow from Sprague Basin	Storage at end of season	Evaporation	Release from Chiloquin Narrows to Upper Klamath Lake	Spill
1920-21	139.3	111.2	47.7	364.2	165.4	—27.6	181.2	0
21-22	86.5	144.9	47.7	325.3	271.9	—37.6	181.2	0
22-23	42.7	117.7	47.7	209.2	259.0	—38.9	183.2	0
23-24	12.5	102.1	47.7	162.3	32.3	—32.7	356.3	0
24-25	106.5	119.2	47.7	273.4	103.4	—21.1	181.2	0
1925-26	14.4	102.5	47.7	164.6	10.0	—18.9	239.1	0
26-27	165.9	189.1	47.7	428.9	165.9	—32.1	240.9	0
27-28	89.7	153.4	47.7	347.2	289.4	—42.5	181.2	0
28-29	28.2	117.8	47.7	193.7	262.4	—39.5	181.2	0
29-30	28.3	128.9	47.7	204.9	247.1	—39.0	181.2	0
1930-31	5.8	95.6	40.8	142.2	176.5	—31.6	181.2	0
31-32	57.4	114.4	44.1	215.9	180.6	—30.6	181.2	0
32-33	30.5	105.6	40.6	176.7	148.3	—27.8	181.2	0
33-34	7.9	98.1	30.2	136.2	81.5	—21.8	181.2	0
34-35	58.4	116.1	46.1	220.6	74.6	—20.4	207.1	0
1935-36	80.3	141.7	47.7	269.7	137.9	—25.2	181.2	0
36-37	43.4	110.1	47.7	201.2	113.8	—24.4	200.9	0
37-38	182.2	201.4	47.7	474.9	359.9	—47.6	181.2	0
38-39	27.2	106.9	47.7	182.9	308.9	—46.4	181.2	6.3
39-40	108.9	153.8	47.7	327.1	344.1	—50.5	181.2	60.2
1940-41	53.5	134.6	47.7	235.8	334.0	—49.0	181.2	15.7
41-42	94.6	177.9	47.7	338.6	371.3	—52.2	181.2	67.9
42-43	224.5	215.8	47.7	640.0	382.4	—52.3	181.2	395.4
43-44	30.0	125.1	47.7	207.4	327.6	—46.7	181.2	34.3
44-45	64.3	153.7	47.7	268.9	364.1	—51.2	181.2	0
1945-46	108.5	167.1	47.7	389.3	359.3	—50.8	181.2	162.1
46-47	20.2	118.0	47.7	185.9	313.0	—46.6	181.2	4.4
47-48	63.7	145.6	47.7	257.0	341.0	—47.8	181.2	0
48-49	61.9	131.1	47.7	242.9	351.5	—51.2	181.2	0
49-50	73.8	134.5	47.7	263.6	363.1	—50.5	181.2	20.3
1950-51	132.6	214.2	47.7	469.5	359.5	—50.9	181.2	241.0
51-52	189.4	258.9	47.7	651.8	389.7	—52.2	181.2	388.2
Average seasonal	76.0	140.8	46.6	286.6		—39.3	191.8	43.6

TABLE E-3

SEASONAL SUMMARY OF MONTHLY YIELD STUDY, UPPER KLAMATH LAKE WITH ULTIMATE CONDITIONS OF DEVELOPMENT

(In 1,000 acre-feet)

Gross storage capacity: 766,000 acre-feet
Active storage capacity: 483,000 acre-feet

Seasonal yield: 780,000 acre-feet

Season	Historical inflow to Upper Klamath Lake less Sprague River flow	Irrigation depletion in Upper Klamath area and Wood River area	Inflow to Upper Klamath Lake[1]	Swan Lake and "A" Canal demands	Irrigation demands below Upper Klamath Lake	Lost River and return flows[2]	Total irrigation demand on Upper Klamath Lake	Power release	Total release	Spill	Evaporation	Storage at end of season	Lost River return flows	Accretions and depletions, Klamath River from Link River to Keno	Return flows from deliveries to California	Flow at Keno
1920-21	1,248.3	24.6	1,404.9	251.0	480.0	225.0	638.2	200.0	838.2	230.3	—256.7	362.7	132.2	+70.8	49.9	683.2
21-22	1,047.9	24.6	1,204.5	251.0	480.0	182.0	604.6	200.0	804.6	156.7	—261.1	344.8	55.6	+122.4	49.9	584.6
22-23	943.4	24.6	1,102.0	251.0	480.0	84.0	662.9	200.0	862.9	48.5	—252.4	283.0	15.9	+105.1	49.9	419.4
23-24	837.3	24.6	1,169.0	251.0	480.0	44.0	698.0	200.0	898.0	0	—270.8	283.2	11.0	—38.2	49.9	222.7
24-25	973.8	24.6	1,130.4	251.0	480.0	91.0	661.9	200.0	861.9	28.1	—221.0	302.6	21.9	+18.8	49.9	318.7
1925-26	726.7	24.6	941.2	251.0	305.3	65.0	509.2	183.5	692.7	0	—268.1	283.0	17.9	+10.9	49.9	262.2
26-27	882.9	24.6	1,099.2	251.0	480.0	123.0	636.2	200.0	836.2	0	—263.0	283.0	28.2	+24.4	49.9	302.5
27-28	901.5	24.6	1,058.1	251.0	480.0	219.0	585.2	200.0	785.2	30.6	—138.5	386.8	73.2	+14.0	49.9	367.7
28-29	768.6	24.6	925.2	251.0	480.0	174.0	597.2	200.0	797.2	0	—193.8	321.0	40.2	+20.0	49.9	310.1
29-30	690.3	24.6	846.9	233.9	449.0	169.0	547.1	200.0	747.1	0	—137.6	283.2	33.2	—3.0	46.8	277.0
1930-31	621.6	24.6	778.2	166.2	324.8	120.0	402.2	200.0	602.2	0	—176.2	283.0	31.2	—6.0	34.3	259.5
31-32	674.6	24.6	831.2	201.9	390.3	144.0	484.4	200.0	684.4	0	—146.8	283.0	36.2	0	40.2	276.4
32-33	713.0	24.6	869.6	215.8	415.5	142.0	520.5	200.0	720.5	0	—149.1	283.0	31.2	—7.0	43.1	267.3
33-34	701.2	24.6	857.8	194.2	375.4	127.0	474.8	200.0	674.8	0	—183.0	283.0	32.2	—18.0	37.1	251.3
34-35	742.1	24.6	924.6	236.6	453.6	149.0	579.4	200.0	779.4	0	—145.2	283.0	38.2	0	46.5	284.7
1935-36	769.6	24.6	926.2	251.0	480.0	202.0	590.2	200.0	790.2	0	—117.9	301.1	61.2	+17.0	49.7	327.9
36-37	727.2	24.6	903.5	251.0	480.0	171.0	595.2	200.0	795.2	0	—121.4	288.0	35.2	+7.0	49.9	292.1
37-38	984.8	24.6	1,141.4	251.0	480.0	506.0	563.9	200.0	763.9	126.8	—94.0	444.7	338.9	+21.0	49.9	736.6
38-39	816.4	24.6	979.3	251.0	480.0	177.0	595.2	200.0	795.2	59.8	—185.9	383.1	41.2	—3.0	49.9	347.9
39-40	826.6	24.6	1,043.4	251.0	480.0	299.0	590.2	200.0	790.2	113.0	—147.7	375.6	158.2	+13.0	49.9	534.1
1940-41	772.7	24.6	945.0	251.0	480.0	205.0	595.2	200.0	795.2	0	—131.9	393.5	69.2	+18.0	49.9	337.1
41-42	841.4	24.6	1,065.9	251.0	480.0	308.0	592.2	200.0	792.2	69.6	—198.5	399.1	169.2	+36.0	49.9	524.7
42-43	1,192.2	24.6	1,744.2	251.0	480.0	420.0	567.2	200.0	767.2	710.5	—154.3	511.3	256.2	+40.0	49.9	1,256.6
43-44	933.7	24.6	1,124.6	251.0	480.0	184.0	597.2	200.0	797.2	222.7	—206.3	409.7	50.2	+11.0	49.9	533.8
44-45	850.6	24.6	1,007.2	251.0	480.0	227.0	593.2	200.0	793.2	24.9	—189.5	409.3	89.2	+5.0	49.9	369.0
1945-46	1,029.0	24.6	1,347.7	251.0	480.0	303.0	580.2	200.0	780.2	302.3	—204.0	470.5	152.2	—8.0	49.9	696.4
46-47	885.3	24.6	1,046.3	251.0	480.0	185.0	595.2	200.0	795.2	105.1	—212.2	404.3	49.2	14.0	49.9	390.2
47-48	809.7	24.6	966.3	251.0	480.0	199.0	599.2	200.0	799.2	32.8	—145.5	393.1	67.2	+21.9	49.9	371.8
48-49	931.4	24.6	1,088.0	251.0	480.0	170.0	599.2	200.0	799.2	66.0	—194.4	421.5	38.2	+29.8	49.9	383.9
49-50	970.8	24.6	1,147.7	251.0	480.0	217.0	597.2	200.0	797.2	168.5	—210.8	392.7	83.2	+47.0	49.9	548.6
1950-51	1,217.9	24.6	1,615.5	251.0	480.0	415.0	571.2	200.0	771.2	638.6	—150.6	447.8	255.2	+31.5	49.9	1,175.2
51-52	1,544.5	24.6	2,089.3	251.0	480.0	506.0	563.9	200.0	763.9	932.2	—242.7	598.3	338.9	+160.6	49.9	1,681.6
Average seasonal	893.1	24.6	1,103.9	243.0	459.8	211.0	580.9	199.5	780.4	127.1	—186.6		89.1	+23.4	48.3	487.4

(1) Including release from Chiloquin Narrows Reservoir to Upper Klamath Lake shown on Table E-2.
(2) Only monthly amounts equal to or less than the monthly irrigation demand in service area below Upper Klamath Lake were used to satisfy the irrigation demands.

TABLE E-4

SEASONAL SUMMARY OF MONTHLY YIELD STUDY, MONTAGUE RESERVOIR ON SHASTA RIVER WITH PRESENT IMPAIRED FLOW OF SHASTA RIVER

(In acre-feet)

Storage capacity: 87,000 acre-feet

Seasonal yield: 84,000 acre-feet

Season	Present impaired flow	Accretion from development	Storage at end of season	Evaporation	Stream flow maintenance release	Irrigation release	Spill
1921-22	81,100	18,600	75,200	6,000	22,000	62,000	17,200
22-23	78,300	18,600	67,700	6,100	22,000	62,000	13,000
23-24	61,900	18,600	61,500	4,800	22,000	62,000	20,400
24-25	134,200	18,600	32,800	7,100	22,000	62,000	21,300
1925-26	84,600	18,600	73,200	6,200	22,000	62,000	27,800
26-27	191,700	18,600	58,400	6,500	22,000	62,000	103,700
27-28	114,500	18,600	74,500	5,600	22,000	62,000	70,000
28-29	71,300	18,600	48,000	5,500	22,000	62,000	5,300
29-30	77,100	18,600	43,100	5,800	22,000	62,000	0
1930-31	63,400	18,600	49,000	5,100	22,000	62,000	0
31-32	65,500	18,600	41,900	4,900	22,000	62,000	0
32-33	63,800	18,600	37,100	4,500	22,000	62,000	0
33-34	55,600	18,600	31,000	3,600	22,000	62,000	0
34-35	63,000	18,600	17,600	3,500	22,000	62,000	0
1935-36	75,100	18,600	11,700	3,900	22,000	62,000	0
36-37	65,500	18,600	17,500	3,400	22,000	62,000	0
37-38	196,700	18,600	14,200	6,900	22,000	62,000	65,900
38-39	72,400	18,600	72,700	5,200	22,000	62,000	32,500
39-40	129,800	18,600	42,000	6,300	22,000	62,000	39,600
1940-41	189,700	18,600	60,500	6,600	22,000	62,000	105,100
41-42	183,800	18,600	73,100	6,500	22,000	62,000	116,300
42-43	89,800	18,600	68,700	6,000	22,000	62,000	26,100
43-44	58,700	18,600	61,000	5,400	22,000	62,000	0
44-45	78,100	18,600	48,900	6,200	22,000	62,000	900
1945-46	100,200	18,600	54,500	5,600	22,000	62,000	34,800
46-47	72,400	18,600	48,900	5,200	22,000	62,000	7,800
47-48	90,100	18,600	42,900	6,100	22,000	62,000	3,900
48-49	93,700	18,600	57,600	5,500	22,000	62,000	28,400
49-50	84,500	18,600	52,000	5,600	22,000	62,000	16,100
1950-51	140,400	18,600	49,400	5,800	22,000	62,000	66,700
51-52	149,000	18,600	51,900	6,300	22,000	62,000	66,700
52-53	170,900	18,600	62,500	6,300	22,000	62,000	97,000
Average seasonal	101,500	18,600		5,600	22,000	62,000	30,800

TABLE E-5

SEASONAL SUMMARY OF MONTHLY YIELD STUDY, MONTAGUE RESERVOIR ON SHASTA RIVER WITH ACCRETION FROM WATER IMPORTED FROM KLAMATH RIVER

(In acre-feet)

Storage capacity: 87,000 acre-feet

Seasonal yield: 105,000 acre-feet

Season	Present impaired flow	Accretion from development and imported water	Storage at end of season	Evaporation	Stream flow maintenance release	Irrigation release	Spill
1921-22	81,100	75,900	87,000	6,100	22,000	105,000	34,300
22-23	78,300	75,900	76,600	5,900	22,000	105,000	29,300
23-24	61,900	75,900	68,600	4,500	22,000	105,000	37,700
24-25	134,200	75,900	37,200	6,600	22,000	105,000	30,000
1925-26	84,600	75,900	83,700	5,900	22,000	105,000	46,900
26-27	191,700	75,900	64,400	6,500	22,000	105,000	113,800
27-28	114,500	75,900	84,700	6,000	22,000	105,000	81,100
28-29	71,300	75,900	58,000	5,100	22,000	105,000	25,600
29-30	77,100	75,900	47,500	5,300	22,000	105,000	13,700
1930-31	63,400	75,900	53,500	4,800	22,000	105,000	14,800
31-32	65,500	75,900	46,200	5,200	22,000	105,000	7,100
32-33	63,800	75,900	48,300	5,200	22,000	105,000	6,100
33-34	55,600	75,900	49,700	4,900	22,000	105,000	2,100
34-35	63,000	75,900	47,200	5,200	22,000	105,000	6,100
1935-36	75,100	75,900	47,800	5,200	22,000	105,000	18,300
36-37	65,500	75,900	48,300	5,500	22,000	105,000	3,600
37-38	196,700	75,900	53,600	6,600	22,000	105,000	109,300
38-39	72,400	75,900	83,300	5,000	22,000	105,000	53,200
39-40	129,800	75,900	46,400	5,800	22,000	105,000	48,100
1940-41	189,700	75,900	71,200	6,600	22,000	105,000	119,700
41-42	183,800	75,900	83,500	6,700	22,000	105,000	130,700
42-43	89,800	75,900	78,800	6,100	22,000	105,000	40,000
43-44	58,700	75,900	71,400	5,500	22,000	105,000	15,200
44-45	78,100	75,900	58,300	5,300	22,000	105,000	20,800
1945-46	100,200	75,900	59,200	5,000	22,000	105,000	49,400
46-47	72,400	75,900	53,900	4,800	22,000	105,000	23,100
47-48	90,100	75,900	47,300	5,800	22,000	105,000	18,300
48-49	93,700	75,900	62,200	5,000	22,000	105,000	43,300
49-50	84,500	75,900	56,500	5,200	22,000	105,000	30,900
1950-51	140,400	75,900	53,800	5,300	22,000	105,000	81,400
51-52	149,000	75,900	56,400	6,000	22,000	105,000	78,200
52-53	170,900	75,900	70,100	6,000	22,000	105,000	108,900
Average seasonal	101,500	75,900		5,600	22,000	105,000	45,100

TABLE E-6

SEASONAL SUMMARY OF MONTHLY YIELD STUDY, GRENADA RANCH RESERVOIR ON SHASTA RIVER

(In acre-feet)

Storage capacity: 22,800 acre-feet | Seasonal yield: 20,000 acre-feet

Season	Inflow	Storage at end of season	Evaporation	Release for downstream water rights	Irrigation release	Spill
1920-21	116,300	1,400	1,700	77,300	20,000	16,100
21-22	112,900	2,600	1,900	75,500	20,000	12,600
22-23	110,100	5,500	1,800	74,800	20,000	15,900
23-24	103,300	3,100	1,500	70,100	20,000	12,900
24-25	116,700	1,900	2,000	79,800	20,000	13,500
1925-26	107,900	3,300	1,800	73,300	20,000	13,400
26-27	128,200	2,700	2,300	78,500	20,000	21,700
27-28	114,700	8,400	2,200	76,200	20,000	19,300
28-29	108,200	5,400	1,800	74,300	20,000	14,800
29-30	109,800	2,700	1,700	74,800	20,000	12,500
1930-31	106,400	3,500	1,800	73,500	20,000	12,700
31-32	108,500	1,900	1,700	74,300	20,000	11,600
32-33	108,500	2,800	1,700	74,300	20,000	12,500
33-34	104,900	2,800	1,700	71,400	20,000	12,300
34-35	108,900	2,300	1,800	73,900	20,000	11,400
1935-36	110,300	4,100	2,000	74,100	20,000	14,400
36-37	114,200	3,900	2,300	75,700	20,000	13,600
37-38	134,100	6,500	2,700	76,900	20,000	30,500
38-39	106,800	10,500	1,800	72,000	20,000	19,900
39-40	123,600	3,600	2,800	75,900	20,000	21,500
1940-41	132,800	7,000	2,700	79,100	20,000	27,500
41-42	120,600	10,500	2,500	77,200	20,000	22,500
42-43	116,200	8,900	1,900	75,200	20,000	23,200
43-44	108,500	4,800	1,800	74,200	20,000	14,100
44-45	114,700	3,200	2,300	76,100	20,000	12,900
1945-46	115,400	6,600	2,400	75,800	20,000	17,300
46-47	108,900	6,500	1,900	74,200	20,000	15,800
47-48	118,200	3,500	2,300	76,500	20,000	13,800
48-49	113,800	9,100	2,200	75,100	20,000	20,300
49-50	111,100	5,300	2,300	74,800	20,000	15,000
1950-51	117,300	4,300	2,000	74,500	20,000	19,900
51-52	126,800	5,200	2,900	77,100	20,000	22,400
Average seasonal	114,300		2,100	75,200	20,000	16,800

TABLE E-7

SEASONAL SUMMARY OF MONTHLY YIELD STUDY, TABLE ROCK RESERVOIR ON LITTLE SHASTA RIVER

(In acre-feet)

Storage capacity: 10,000 acre-feet

Seasonal yield: 11,800 acre-feet

Season	Inflow	Storage at end of season	Evaporation	Irrigation release	Spill
1921-22	19,000	9,000	600	11,800	9,700
22-23	18,000	5,900	800	11,800	6,900
23-24	8,000	4,400	500	11,800	0
24-25	28,000	100	900	11,800	6,900
1925-26	14,500	8,500	600	11,800	5,400
26-27	43,000	5,200	800	11,800	25,800
27-28	23,000	9,800	700	11,800	14,800
28-29	13,000	5,500	900	11,800	2,000
29-30	15,500	3,800	900	11,800	4,300
1930-31	10,500	2,300	600	11,800	0
31-32	13,500	400	700	11,800	0
32-33	13,500	1,400	800	11,800	0
33-34	10,500	2,300	600	11,800	0
34-35	12,500	400	700	11,800	0
1935-36	15,000	400	900	11,800	0
36-37	14,000	2,700	900	11,800	200
37-38	42,000	3,800	700	11,800	27,400
38-39	11,000	5,900	900	11,800	1,500
39-40	26,200	2,700	800	11,800	13,100
1940-41	37,300	3,200	700	11,800	23,400
41-42	31,500	4,600	700	11,800	17,900
42-43	28,500	5,700	800	11,800	15,200
43-44	13,000	6,400	800	11,800	3,200
44-45	20,500	3,600	900	11,800	6,400
1945-46	21,000	5,000	700	11,800	8,600
46-47	13,500	4,900	900	11,800	3,000
47-48	26,000	2,700	800	11,800	9,300
48-49	20,000	6,800	700	11,800	8,800
49-50	16,500	5,500	900	11,800	3,300
1950-51	32,000	6,000	600	11,800	20,000
51-52	38,500	5,600	600	11,800	24,200
Average seasonal	20,400		700	11,800	8,200

TABLE E-8

SEASONAL SUMMARY OF MONTHLY YIELD STUDY, IRON GATE RESERVOIR ON KLAMATH RIVER WITH ULTIMATE IMPAIRED INFLOW

(In acre-feet)

Active storage capacity: 35,400 acre-feet

Seasonal yield: 122,000 acre-feet

Season	Ultimate inflow to Copco Lake	Inflow Copco Lake to Iron Gate Reservoir	Total inflow	Reservoir evaporation	Irrigation diversion to Shasta Valley	Spill
1920-21	873,500	152,100	1,025,600	1,700	122,000	901,900
21-22	795,500	100,000	895,500	1,700	122,000	771,800
22-23	581,400	78,400	659,800	1,700	122,000	536,100
23-24	427,700	84,600	512,300	1,700	122,000	388,600
24-25	470,600	108,800	579,400	1,700	122,000	455,700
1925-26	447,200	101,600	548,800	1,700	122,000	425,100
26-27	532,600	129,400	662,000	1,700	122,000	538,300
27-28	557,700	112,400	670,100	1,700	122,000	546,400
28-29	495,100	81,000	576,100	1,700	122,000	452,400
29-30	472,000	84,600	556,600	1,700	122,000	432,900
1930-31	404,500	44,300	448,800	1,700	122,000	325,100
31-32	466,400	113,400	579,800	1,700	122,000	456,100
32-33	467,300	124,300	591,600	1,700	122,000	467,900
33-34	416,300	66,000	482,300	1,700	122,000	358,600
34-35	469,700	109,800	579,500	1,700	122,000	455,800
1935-36	537,900	116,000	653,900	1,700	122,000	530,200
36-37	492,100	101,600	593,700	1,700	122,000	470,000
37-38	991,600	219,100	1,210,700	1,700	122,000	1,087,000
38-39	526,600	74,800	601,400	1,700	122,000	477,700
39-40	700,500	134,100	834,600	1,700	122,000	710,900
1940-41	537,100	118,600	655,700	1,700	122,000	532,000
41-42	715,700	124,300	840,000	1,700	122,000	716,300
42-43	1,426,900	120,700	1,547,600	1,700	122,000	1,423,900
43-44	734,100	68,600	802,700	1,700	122,000	679,000
44-45	549,000	124,300	673,300	1,700	122,000	549,600
1945-46	906,800	154,700	1,061,500	1,700	122,000	937,800
46-47	555,400	68,600	624,000	1,700	122,000	500,300
47-48	556,600	145,500	702,100	1,700	122,000	578,400
48-49	580,900	95,500	676,400	1,700	122,000	552,700
49-50	736,500	131,500	868,000	1,700	122,000	744,300
1950-51	1,397,900	206,400	1,604,300	1,700	122,000	1,480,600
51-52	2,009,800	167,500	2,177,300	1,700	122,000	2,053,600
Average seasonal	682,300	114,500	796,800	1,700	122,000	673,000

TABLE E-9

SEASONAL SUMMARY OF MONTHLY YIELD STUDY, HIGHLAND RESERVOIR ON MOFFETT CREEK

(In acre-feet)

Storage capacity: 26,200 acre-feet

Seasonal yield: 9,800 acre-feet

Season	Inflow	Storage at end of season	Evaporation	Irrigation release	Spill
1920-21	19,600	17,100	700	9,800	0
21-22	7,900	14,500	700	9,800	0
22-23	7,000	11,100	600	9,800	0
23-24	2,700	3,500	500	9,800	0
24-25	18,500	11,300	900	9,800	0
1925-26	8,000	8,900	600	9,800	0
26-27	24,000	22,100	1,000	9,800	0
27-28	10,700	20,100	800	9,800	2,100
28-29	5,900	15,500	700	9,800	0
29-30	7,400	12,500	600	9,800	0
1930-31	4,800	7,000	500	9,800	0
31-32	10,200	6,700	700	9,800	0
32-33	9,800	5,900	800	9,800	0
33-34	5,700	1,300	500	9,800	0
34-35	11,200	2,200	500	9,800	0
1935-36	11,300	3,100	600	9,800	0
36-37	9,400	2,200	500	9,800	0
37-38	29,400	20,500	1,300	9,800	0
38-39	7,400	17,200	900	9,800	0
39-40	13,200	19,600	1,000	9,800	0
1940-41	13,000	21,400	900	9,800	500
41-42	17,100	22,200	900	9,800	5,600
42-43	19,900	21,600	900	9,800	9,800
43-44	6,100	17,100	800	9,800	9,200
44-45	10,100	16,500	900	9,800	0
1945-46	15,300	21,000	1,000	9,800	0
46-47	7,700	18,000	900	9,800	0
47-48	12,000	19,300	900	9,800	0
48-49	9,900	18,500	900	9,800	0
49-50	11,700	19,400	1,000	9,800	0
1950-51	21,800	21,300	900	9,800	0
51-52	24,300	22,900	900	9,800	12,000
Average seasonal	12,300		800	9,800	1,200

TABLE E-10

ANNUAL SUMMARY OF MONTHLY YIELD STUDY, CALLAHAN RESERVOIR ON SCOTT RIVER

(In acre-feet)

Storage capacity: 133,000 acre-feet

Annual yield: 71,400 acre-feet

Calendar year	Inflow	Storage at end of year	Evaporation	Stream flow maintenance release	Irrigation release	Spill
1922	65,700	133,000	3,200	9,700	61,700	30,200
1923	55,700	93,900	3,000	9,700	61,700	0
1924	36,100	75,200	2,000	9,700	61,700	0
1925	141,000	37,900	3,700	9,700	61,700	3,000
1926	101,100	100,800	3,200	9,700	61,700	7,900
1927	168,600	119,400	3,500	9,700	61,700	103,100
1928	82,400	110,000	3,400	9,700	61,700	23,900
1929	52,800	93,700	2,600	9,700	61,700	0
1930	50,400	72,500	2,600	9,700	61,700	0
1931	43,100	48,900	1,800	9,700	61,700	0
1932	81,400	18,800	2,000	9,700	61,700	0
1933	82,400	26,800	2,000	9,700	61,700	0
1934	57,800	35,800	1,800	9,700	61,700	0
1935	80,800	20,400	2,200	9,700	61,700	0
1936	90,200	27,600	2,500	9,700	61,700	0
1937	122,500	43,900	2,500	9,700	61,700	0
1938	206,000	92,500	3,400	9,700	61,700	116,600
1939	57,900	107,100	3,200	9,700	61,700	3,400
1940	113,900	87,000	3,300	9,700	61,700	28,000
1941	121,200	98,200	3,400	9,700	61,700	22,700
1942	146,800	121,900	3,300	9,700	61,700	63,400
1943	136,500	130,600	3,300	9,700	61,700	90,700
1944	51,300	101,700	3,000	9,700	61,700	0
1945	99,500	78,600	3,100	9,700	61,700	0
1946	114,000	103,600	3,400	9,700	61,700	36,900
1947	59,400	105,900	3,300	9,700	61,700	0
1948	100,900	90,600	3,400	9,700	61,700	12,700
1949	77,200	104,000	3,300	9,700	61,700	12,700
1950	152,000	93,800	3,400	9,700	61,700	38,000
1951	143,000	133,000	3,300	9,700	61,700	86,300
1952	187,500	115,000	3,400	9,700	61,700	116,400
Average annual	99,300		3,000	9,700	61,700	25,700

TABLE E-11

SEASONAL SUMMARY OF MONTHLY YIELD STUDY, GROUSE CREEK RESERVOIR ON SCOTT RIVER

(In acre-feet)

Storage capacity: 48,500 acre-feet

Seasonal yield: 19,800 acre-feet

Season	Inflow	Storage at end of season	Evaporation	Irrigation release	Spill
1920-21	43,500	40,100	2,100	19,800	23,500
21-22	15,800	38,200	2,000	19,800	0
22-23	14,000	32,200	1,800	19,800	0
23-24	5,400	24,600	1,300	19,800	0
24-25	37,000	8,900	1,700	19,800	0
1925-26	16,100	24,400	1,700	19,800	0
26-27	47,900	19,000	2,200	19,800	6,400
27-28	21,400	38,600	2,100	19,800	3,600
28-29	11,700	34,400	1,800	19,800	0
29-30	14,900	24,500	1,600	19,800	0
1930-31	9,500	18,100	1,200	19,800	0
31-32	20,500	6,600	1,100	19,800	0
32-33	19,600	6,200	900	19,800	0
33-34	11,400	5,100	800	13,000	0
34-35	22,500	2,700	1,000	19,800	0
1935-36	22,700	4,500	1,100	19,800	0
36-37	18,900	6,200	900	19,800	0
37-38	58,700	4,400	2,000	19,800	2,500
38-39	14,800	38,800	2,000	19,800	0
39-40	26,300	31,800	2,100	19,800	2,100
1940-41	26,000	34,100	2,100	19,800	1,000
41-42	34,100	37,100	2,200	19,800	10,400
42-43	39,800	38,900	2,100	19,800	19,000
43-44	12,200	37,700	1,900	19,800	0
44-45	20,100	28,200	1,800	19,800	0
1945-46	30,600	26,700	2,000	19,800	0
46-47	15,400	35,500	1,900	19,800	0
47-48	24,000	29,200	1,900	19,800	0
48-49	19,800	31,400	1,800	19,800	0
49-50	23,300	29,600	1,800	19,800	0
1950-51	43,600	31,200	2,100	19,800	16,200
51-52	48,700	36,700	2,200	19,800	23,300
Average seasonal	24,700		1,700	19,600	3,400

TABLE E-12

SEASONAL SUMMARY OF MONTHLY YIELD STUDY, ETNA RESERVOIR ON FRENCH CREEK

(In acre-feet)

Storage capacity: 12,000 acre-feet

Seasonal yield: 11,000 acre-feet

Season	Inflow	Storage at end of season	Evaporation	Irrigation release	Spill
1920-21	71,300	8,400	800	11,000	59,400
21-22	25,400	8,400	800	11,000	15,600
22-23	20,900	6,300	800	11,000	9,000
23-24	1,900	6,500	500	7,000	0
24-25	57,800	800	800	11,000	38,600
1925-26	26,500	8,000	800	11,000	17,800
26-27	70,000	5,000	800	11,000	55,600
27-28	35,700	7,600	800	11,000	25,700
28-29	15,900	5,800	800	11,000	3,800
29-30	27,100	6,000	800	11,000	16,700
1930-31	12,400	4,500	700	11,000	1,300
31-32	33,900	3,900	800	11,000	19,600
32-33	33,100	6,500	900	11,000	19,900
33-34	16,000	7,700	800	11,000	8,300
34-35	36,200	3,600	800	11,000	21,600
1935-36	38,200	6,400	800	11,000	26,300
36-37	34,000	6,400	800	11,000	21,600
37-38	85,500	6,800	900	11,000	72,800
38-39	22,400	7,700	800	11,000	13,400
39-40	44,700	5,000	800	11,000	32,100
1940-41	41,500	5,800	800	11,000	27,900
41-42	44,600	7,600	800	11,000	33,100
42-43	62,500	7,200	800	11,000	51,000
43-44	17,400	7,000	800	11,000	6,400
44-45	36,700	6,200	800	11,000	24,500
1945-46	53,400	6,400	800	11,000	41,400
46-47	22,400	6,600	800	11,000	11,900
47-48	41,400	5,300	800	11,000	27,500
48-49	30,100	7,400	800	11,000	19,400
49-50	39,600	6,200	800	11,000	27,300
1950-51	65,100	6,600	800	11,000	53,800
51-52	72,400	6,100	900	11,000	58,200
Average seasonal	38,600		800	10,900	26,900

TABLE E-13

SEASONAL SUMMARY OF MONTHLY YIELD STUDY, MUGGINSVILLE RESERVOIR ON MILL CREEK

(In acre-feet)

Storage capacity: 23,000 acre-feet

Seasonal yield: 16,000 acre-feet

Season	Inflow to reservoir			Storage at end of season	Evaporation	Irrigation release	Spill
	Runoff of Mill Creek	Water diverted from Shackleford Creek	Total				
1920-21	13,900	7,500	21,400	16,000	2,100	16,000	5,300
21-22	5,100	11,400	16,500	14,000	2,000	16,000	0
22-23	4,500	11,600	16,100	12,500	1,900	16,000	0
23-24	1,700	3,700	5,400	10,700	1,100	14,000	0
24-25	11,900	19,400	31,300	1,100	2,000	16,000	900
1925-26	5,200	8,100	13,300	13,500	1,800	16,000	0
26-27	15,400	13,800	29,200	9,000	2,100	16,000	5,800
27-28	6,900	9,000	15,900	14,300	1,900	16,000	1,300
28-29	3,800	9,200	13,000	11,000	1,600	16,000	0
29-30	4,800	12,600	17,400	6,400	1,600	16,000	0
1930-31	3,000	7,300	10,300	6,200	1,100	14,000	0
31-32	6,600	18,300	24,900	1,400	1,500	16,000	0
32-33	6,300	17,000	23,300	8,800	1,900	16,000	0
33-34	3,700	7,700	11,400	14,100	1,700	16,000	0
34-35	7,200	15,200	22,400	7,800	2,000	16,000	0
1935-36	7,300	11,300	18,600	12,200	2,000	16,000	1,000
36-37	6,100	13,500	19,600	11,800	2,000	16,000	0
37-38	18,800	8,200	27,000	13,400	2,100	16,000	7,600
38-39	4,700	7,700	12,400	14,700	1,800	16,000	0
39-40	8,400	13,200	21,600	9,400	1,900	16,000	2,000
1940-41	8,300	13,400	21,700	11,100	2,100	16,000	1,000
41-42	10,900	11,600	22,500	13,700	2,100	16,000	3,700
42-43	12,800	11,400	24,200	14,500	2,100	16,000	5,500
43-44	3,900	8,600	12,500	15,000	1,800	16,000	0
44-45	6,400	14,700	21,100	9,700	2,000	16,000	0
1945-46	9,800	10,900	20,700	12,000	2,100	16,000	1,700
46-47	4,900	9,800	14,700	13,900	1,900	16,000	0
47-48	7,700	13,700	21,400	10,700	2,100	16,000	0
48-49	6,400	9,800	16,200	14,100	2,000	16,000	0
49-50	7,500	11,800	19,300	12,300	2,000	16,000	0
1950-51	14,000	10,400	24,400	13,600	2,000	16,000	7,100
51-52	15,600	10,600	26,200	12,800	2,100	16,000	5,000
Average seasonal	8,300	10,900	19,200		1,900	15,900	1,500

TABLE E-14

SEASONAL SUMMARY OF MONTHLY YIELD STUDY, LAYMAN RESERVOIR ON HAYFORK CREEK

(In acre-feet)

Storage capacity: 21,500 acre-feet

Seasonal yield: 20,600 acre-feet

Season	Inflow	Storage at end of season	Evaporation	Irrigation release	Stream flow maintenance release	Spill
1920-21	160,500	8,000	900	17,000	3,600	169,400
21-22	106,100	11,300	900	17,000	3,600	87,600
22-23	68,300	8,300	900	17,000	3,600	48,300
23-24	32,300	6,800	800	17,000	3,600	16,700
24-25	142,100	1,000	900	17,000	3,600	112,000
1925-26	93,800	9,600	800	17,000	3,600	76,400
26-27	136,700	5,600	900	17,000	3,600	111,600
27-28	131,200	9,200	900	17,000	3,600	111,400
28-29	78,100	7,500	1,000	17,000	3,600	56,200
29-30	78,600	7,800	900	17,000	3,600	59,200
1930-31	42,200	5,700	800	17,000	3,600	22,400
31-32	105,600	4,100	1,000	17,000	3,600	80,000
32-33	106,300	8,100	1,000	17,000	3,600	83,600
33-34	60,300	9,200	800	17,000	3,600	44,600
34-35	127,300	3,500	1,000	17,000	3,600	100,800
1935-36	133,600	8,400	900	17,000	3,600	111,000
36-37	88,500	9,500	1,000	17,000	3,600	67,900
37-38	278,700	8,500	1,000	17,000	3,600	253,300
38-39	81,700	12,300	900	17,000	3,600	66,700
39-40	166,000	5,800	1,000	17,000	3,600	141,400
1940-41	153,200	8,800	900	17,000	3,600	135,000
41-42	136,400	5,500	1,000	17,000	3,600	110,600
42-43	185,200	9,600	1,000	17,000	3,600	163,000
43-44	66,000	10,200	1,000	17,000	3,600	47,000
44-45	131,800	7,600	1,000	17,000	3,600	108,700
1945-46	167,100	9,100	1,000	17,000	3,600	144,600
46-47	67,900	10,000	900	17,000	3,600	49,100
Average seasonal	115,800		900	17,000	3,600	95,500

TABLE E-15

ANNUAL SUMMARY OF MONTHLY YIELD STUDY, MOREHOUSE RESERVOIR ON SALMON RIVER

(In acre-feet)

Storage capacity: 910,000 acre-feet

Average annual yield: 799,000 acre-feet

Calendar year	Inflow	Storage at end of year	Evaporation	Power release	Spill
1921	1,184,100	630,200	15,600	910,900	258,200
1922	678,400	629,600	15,100	647,000	15,700
1923	595,900	630,200	15,200	580,700	0
1924	393,900	630,200	12,900	581,900	0
1925	1,091,600	429,300	15,300	813,300	62,100
1926	937,200	630,200	15,000	857,700	0
1927	1,190,200	694,700	15,600	938,200	300,900
1928	793,600	630,200	15,400	768,300	9,900
1929	528,700	630,200	13,700	572,700	0
1930	587,300	572,500	15,200	549,600	0
1931	402,700	595,000	13,000	574,900	0
1932	775,000	409,800	15,000	550,800	0
1933	791,600	619,000	15,300	688,900	76,200
1934	545,400	630,200	13,600	637,000	0
1935	760,800	525,000	15,300	646,500	0
1936	848,900	624,000	15,500	866,700	0
1937	1,064,400	590,700	15,000	885,600	0
1938	1,488,000	754,500	15,600	876,200	720,500
1939	554,500	630,200	15,000	576,100	0
1940	1,030,900	593,600	15,600	839,400	139,300
1941	1,078,800	630,200	15,200	975,200	25,400
1942	1,140,400	693,200	15,200	1,069,800	0
1943	1,045,500	748,600	15,600	915,500	232,800
1944	522,200	630,200	14,400	558,300	0
1945	1,054,800	579,700	15,300	914,000	0
1946	981,600	705,200	15,300	1,041,300	0
1947	572,100	630,200	14,900	581,900	0
1948	977,300	605,500	15,300	907,700	29,600
1949	667,200	630,200	15,300	666,100	0
1950	1,348,800	616,000	15,300	1,104,600	0
1951	1,158,100	844,900	15,600	962,300	312,400
1952	1,314,700	712,700	15,600	1,006,100	375,500
1953	1,520,300	630,200	15,600	1,307,600	197,100
Average annual	897,700		15,000	799,200	83,500

APPENDIX F
ESTIMATES OF COST

TABLE OF CONTENTS

TABLES

Appendix F

ESTIMATES OF COST

TABLE F-1

ESTIMATED COST OF MONTAGUE DAM AND RESERVOIR

(Based on prices prevailing in Spring of 1956)

Elevation of crest of dam: 2,515 feet, U.S.G.S. datum
Elevation of crest of spillway: 2,500 feet
Height of dam to spillway crest, above stream bed: 93 feet

Storage capacity of reservoir to spillway crest: 87,000 acre-feet
Discharge capacity of spillway with 6-foot freeboard: 7,200 second-feet

Item	Quantity	Unit price	Cost	
CAPITAL COSTS				
Dam				
Diversion and care of stream		lump sum	$10,000	
Stripping and preparation of foundation	226,000 cu.yd.	$0.75	169,500	
Embankment				
Impervious	1,223,100 cu.yd.	.75	917,300	
Pervious	212,100 cu.yd.	3.00	636,300	
Grouting		lump sum	25,000	$1,758,100
Spillway				
Excavation	97,500 cu.yd.	1.50	146,300	
Concrete	2,550 cu.yd.	60.00	153,000	
Reinforcing steel	191,100 lbs.	0.14	26,800	$326,100
Outlet Works				
Excavation	4,800 cu.yd.	5.00	24,000	
Concrete	2,400 cu.yd.	30.00	72,000	
Reinforcing steel	180,000 lbs.	0.14	25,200	
Steel pipe, 72-inch diameter	300,000 lbs.	.30	90,000	
Butterfly valve, 72-inch diameter	2 each	11,250	22,500	
Howell-Bunger valve, 36-inch diameter	1 each	7,500	7,500	
Inlet structures and trashracks		lump sum	$20,000	$261,200
CAPITAL COSTS—Cont.				
Reservoir				
Land and improvements		lump sum	1,440,000	
Public utilities		lump sum	1,021,000	
Clearing		lump sum	30,000	$2,491,000
Subtotal				$4,836,400
Administration and engineering, 10%				483,600
Contingencies, 15%				725,400
Interest during construction				211,600
TOTAL				$6,270,000
ANNUAL COSTS				
Interest, 3.5%				$219,500
Repayment, 0.76%				47,700
Replacement, 0.07%				4,400
General expense, 0.32%				20,100
Operation and maintenance				11,200
TOTAL				$302,900

TABLE F-2

ESTIMATED COST OF NORTH AND SOUTH PUMPING PLANTS

(Based on prices prevailing in Spring of 1956)

Discharge capacity of pumping plants: North, 90 second-feet
South, 169 second-feet

Maximum pumping head:
North, 221 feet
South, 224 feet

Item	Quantity	Unit price	Cost	
CAPITAL COSTS				
North Pumping Plant				
20,500 gpm units	3 each	$170,200	$510,600	
17,500 gpm units	2 each	117,000	234,000	
Valves		lump sum	30,000	
Discharge conduit, 36-inch diameter welded steel pipe	4,020 lin. ft.	17.40	70,000	$844,600
South Pumping Plant				
10,000 gpm units	3 each	96,600	289,800	
10,000 gpm units	2 each	72,600	145,200	
Valves		lump sum	30,000	
Discharge conduit, 30-inch diameter welded steel pipe	3,080 lin.ft.	14.40	44,400	$509,400
Subtotal				$1,354,000
CAPITAL COSTS Cont.				
Administration and engineering, 10%				$135,400
Contingencies, 15%				203,100
Interest during construction				29,600
TOTAL				$1,722,100
ANNUAL COSTS				
Interest, 3.5%				$60,300
Repayment, 0.76%				13,100
Replacement, 1.20%				20,700
Insurance, 0.12%				2,100
General expense, 0.32%				5,500
Operation and maintenance				174,700
Electrical energy				134,300
TOTAL				$410,700

TABLE F-3

ESTIMATED COST OF GRENADA RANCH DAM AND RESERVOIR

(Based on prices prevailing in Spring of 1956)

Elevation of crest of dam: 2,590 feet, U.S.G.S. datum
Elevation of spillway crest: 2,580 feet
Height of dam to spillway crest, above stream bed: 52 feet

Storage capacity of reservoir to spillway crest: 22,800 acre-feet
Discharge capacity of spillway with 4-foot freeboard: 12,000 second-feet

Item	Quantity	Unit price	Cost	
CAPITAL COSTS				
Dam				
Diversion and care of stream		lump sum	$15,000	
Stripping and preparation of foundation	41,300 cu.yd.	$1.00	41,300	
Embankment				
Pervious, salvage	56,900 cu.yd.	0.50	28,500	
Impervious	91,600 cu.yd.	0.60	55,000	
Grouting		lump sum	70,000	$209,800
Spillway				
Excavation, used in dam	33,600 cu.yd.	1.00	33,600	
Concrete	1,365 cu.yd.	35.00	47,800	
Reinforcing steel	102,500 lbs.	0.15	15,400	
Grouting		lump sum	12,000	108,800
Auxiliary Dams				
Stripping and preparation of foundation	14,800 cu.yd.	1.00	14,800	
Embankment	39,000 cu.yd.	0.60	23,400	
Riprap	4,800 cu.yd.	2.50	12,000	
Grouting		lump sum	27,000	77,200
Outlet Works				
Excavation	350 cu.yd.	3.00	1,100	
Backfill	600 cu.yd.	2.00	1,200	
Concrete				
Pipe encasement	280 cu.yd.	40.00	11,200	
Structural	40 cu.yd.	100.00	4,000	
CAPITAL COSTS—Cont.				
Reinforcing steel	32,000 lbs.	0.15	4,800	
Steel pipe	41,500 lbs.	0.30	12,500	
Slide gate, 36-inch diameter and manual controls	2 each	1,500	3,000	
Gate valves, 9-inch diameter and manual controls	5 each	800.00	4,000	$41,800
Reservoir				
Land and improvements		lump sum	665,000	
Public utilities		lump sum	35,000	
Clearing		lump sum	15,000	715,000
Subtotal				$1,152,600
Administration and engineering, 10%				115,300
Contingencies, 15%				172,500
Interest during construction				50,600
Total				$1,491,000
ANNUAL COSTS				
Interest, 3.5%				$52,200
Repayment, 0.76%				11,300
Replacement, 0.07%				1,200
Operation and maintenance				5,000
Total				$69,700

TABLE F-4

ESTIMATED COST OF GRENADA RANCH PUMPING PLANT AND CONDUIT TO YREKA

(Based on prices prevailing in Spring of 1956)

Item	Quantity	Unit price	Cost	
CAPITAL COSTS				
Pumping Plant				
Pump, motor and starter, 900 gpm unit	2 each	$6,500	$13,000	
Filtration plant and pump house		lump sum	65,000	
Valves and special items		lump sum	1,000	$79,000
Conduit				
Steel pipe, 14-inch diameter, #10 gage	57,000 lin.ft.	5.40	307,800	
Valves and special items		lump sum	30,000	337,800
Subtotal				$416,800
Administration and engineering, 10%				$41,700
CAPITAL COSTS—Cont.				
Contingencies, 15%				$62,500
Interest during construction				18,000
TOTAL				$539,000
ANNUAL COSTS				
Interest, 3.5%				$18,900
Repayment, 0.76%				4,100
Replacement				5,400
Operation and maintenance				12,000
Electrical energy				9,500
TOTAL				$49,900

TABLE F-5

ESTIMATED COST OF TABLE ROCK DAM AND RESERVOIR

(Based on prices prevailing in Spring of 1956)

Elevation of crest of dam: 2,900 feet, U.S.G.S. datum
Elevation of crest of spillway: 2,890 feet
Height of dam to spillway crest, above stream bed: 80 feet
Storage capacity of reservoir to spillway crest: 10,000 acre-feet
Discharge capacity of spillway with 6-foot freeboard: 750 second-feet

Item	Quantity	Unit price	Cost	
CAPITAL COSTS				
Dam				
Diversion and care of stream		lump sum	$10,000	
Stripping and preparation of foundation	381,700 cu.yd.	$1.00	381,700	
Excavation				
Impervious	1,255,500 cu.yd.	0.35	439,400	
Pervious	143,700 cu.yd.	1.00	143,700	
Riprap	14,300 cu.yd.	1.00	14,300	
Embankment				
Impervious	1,255,500 cu.yd.	0.20	251,100	
Pervious	143,700 cu.yd.	1.50	215,600	
Salvage	15,000 cu.yd.	0.40	6,000	
Riprap	14,300 cu.yd.	3.00	42,900	
Grouting	5,600 lin.ft.	10.00	56,000	$1,560,700
Saddle Dam				
Stripping and preparation of foundation	17,000 cu.yd.	1.10	18,700	
Excavation				
Impervious	124,800 cu.yd.	0.40	49,900	
Riprap	2,200 cu.yd.	1.20	2,600	
Embankment				
Impervious	124,800 cu.yd.	0.30	37,400	
Riprap	2,200 cu.yd.	3.00	6,600	$115,200
Spillway				
Excavation	23,000 cu.yd.	2.50	57,500	
Concrete	730 cu.yd.	60.00	43,800	
Reinforcing steel	54,800 lbs.	0.14	7,700	$109,000
Outlet Works				
Excavation	3,563 cu.yd.	2.50	8,900	
Concrete, pipe encasement	847 cu.yd.	60.00	50,800	
Reinforcing steel	63,500 lbs.	0.14	8,900	
CAPITAL COSTS—Cont.				
Steel pipe				
12-inch diameter	5,980 lbs.	$0.30	$1,800	
30-inch diameter	26,600 lbs.	.30	8,000	
Trashrack		lump sum	1,000	
High pressure slide gates,				
2.5 feet x 2.5 feet	2 each	6,000	12,000	
1.0 feet x 1.0 feet	1 each	2,000	2,000	
Howell-Bunger valves,				
30-inch diameter	2 each	9,000	18,000	
12-inch diameter	1 each	2,000	2,000	
Miscellaneous metal work		lump sum	5,000	$118,400
Reservoir				
Land and improvements		lump sum	100,000	
Public utilities		lump sum	66,000	
Clearing	100 acres	100.00	10,000	$176,000
Subtotal				$2,079,300
Administration and engineering, 10%				207,900
Contingencies, 15%				311,900
Interest during construction				91,000
TOTAL				$2,690,100
ANNUAL COSTS				
Interest, 3.5%				$94,200
Repayment, 0.76%				20,400
Replacement, 0.07%				1,900
General expense, 0.32%				8,600
Operation and maintenance				5,000
TOTAL				$130,100

TABLE F-6

ESTIMATED COST OF IRON GATE DAM AND RESERVOIR

(Based on prices prevailing in Spring of 1956)

Elevation of crest of dam: 2,305 feet, U.S.G.S. datum
Elevation of crest of spillway: 2,280 feet
Height of dam to spillway crest, above stream bed: 112 feet

Storage capacity of reservoir to spillway crest: 35,400 acre-feet
Discharge capacity of spillway with 5-foot freeboard: 40,000 second-feet

Item	Quantity	Unit price	Cost	
CAPITAL COSTS				
Dam				
Diversion and care of stream		lump sum	$20,000	
Diversion tunnel, 15-foot diameter	610 lin.ft.	$210.00	128,100	
Stripping and preparation of foundation	31,821 cu.yd.	3.00	95,500	
Concrete				
Mass	116,600 cu.yd.	20.00	2,332,000	
Bridge	1,600 sq.ft.	10.00	16,000	
Pre-packed	250 cu.yd.	100.00	25,000	$2,616,600
Outlet Works				
Radial gates	200,600 lbs.	0.35	70,200	
Steel pipe				
48-inch diameter	12,000 lbs.	0.30	3,600	
120-inch diameter	665,000 lbs.	0.30	199,500	
Slide gate, 4 feet x 4 feet		lump sum	25,000	
Regulating valve		lump sum	4,000	
Grouting	1,920 lin.ft.	10.00	19,200	
Trash rack		lump sum	5,000	
Butterfly valve, 120-inch diameter	80,000 lbs.	0.50	40,000	$366,500

Item	Quantity	Unit price	Cost	
CAPITAL COSTS—Cont.				
Reservoir				
Land and improvements		lump sum	19,000	
Clearing		lump sum	76,000	$95,000
Subtotal				$3,078,100
Administration and engineering, 10%				307,800
Contingencies, 15%				461,700
Interest during construction				134,700
TOTAL				$3,982,300
ANNUAL COSTS				
Interest, 3.5%				$139,400
Repayment, 0.76%				30,300
Replacement, 0.07%				2,800
General expense, 0.32%				12,700
Operation and maintenance				6,800
TOTAL				$182,000

TABLE F-7

ESTIMATED COST OF IRON GATE PUMPING PLANT

(Based on prices prevailing in Spring of 1956)

Discharge capacity of pumping plant: 840 second-feet
Maximum pumping head: 336 feet

Item	Quantity	Unit price	Cost	
CAPITAL COSTS				
Pumping plant				
75,000 gpm units	5 each	$640,000	$3,200,000	
Valves		lump sum	75,000	
Discharge conduit, 10-diameter welded steel pipe	1,830 lin.ft.	200.00	366,000	$3,641,000
Subtotal				$3,641,000
Administration and engineering, 10%				364,100
Contingencies, 15%				546,200
Interest during construction				159,300
TOTAL				$4,710,600

Item	Quantity	Unit price	Cost
ANNUAL COSTS			
Interest, 3.5%			$164,900
Repayment, 0.76%			35,800
Replacement, 1.20%			56,500
General expense, 0.32%			15,100
Insurance, 0.12%			5,600
Operation and maintenance			185,000
Electrical energy			315,000
TOTAL			$777,900

TABLE F-8

ESTIMATED COST OF BOGUS CONDUIT

(Based on prices prevailing in Spring of 1956)

Length of lined canal:
Length of tunnel:
Length of steel pipe siphon:
Discharge capacity of conduit: 840 and 770 second-feet

Item	Quantity	Unit price	Cost		Item	Quantity	Unit price	Cost
CAPITAL COSTS					CAPITAL COSTS—Cont.			
Canal					Administration and engineering, 10%			$493,200
Right of way	140 ac.	$100.00	$14,000					
Excavation	547,000 cu.yd.	4.00	2,188,000		Contingencies, 15%			739,800
Embankment	121,000 cu.yd.	0.25	30,200		Interest during construction			215,800
Trimming	264,000 sq.yd.	2.00	528,000					
Lining	264,000 sq.yd.	2.50	660,000	$3,420,200	TOTAL			$6,380,700
Tunnel					ANNUAL COSTS			
12.5-foot diameter lined horseshoe tunnel	2,100 lin.ft.	319.00		669,900	Interest, 3.5%			$223,300
					Repayment, 0.76%			48,500
Siphon*					Replacement			13,000
10.0-foot diameter welded steel pipe	4,550 lin.ft.	185.00		841,800	General expense 0.32%			20,400
					Operation and maintenance			57,000
Subtotal				$4,931,900	TOTAL			$362,200

TABLE F-9

ESTIMATED COST OF AGER PUMPING PLANT

(Based on prices prevailing in Spring of 1956)

Discharge capacity of pumping plant: 770 second-feet
Maximum pumping head: 234 feet

Item	Quantity	Unit price	Cost		Item	Quantity	Unit price	Cost
CAPITAL COSTS					ANNUAL COSTS			
Pumping plant					Interest, 3.5%			$122,100
90,000 gpm units	4 each	$575,000	$2,300,000		Repayment, 0.76%			26,500
Valves		lump sum	60,000		Replacement, 1.20%			41,900
Discharge conduit, 9.5 foot diameter welded steel pipe	2,400 lin.ft.	140.00	336,000	$2,696,000	General expense, 0.32%			11,200
					Insurance, 0.12%			4,200
					Operation and maintenance			136,000
					Electrical energy			207,000
Subtotal				$2,696,000	TOTAL			$548,900
Administration and engineering, 10%				269,600				
Contingencies, 15%				404,400				
Interest during construction				118,000				
TOTAL				$3,488,000				

TABLE F-10

ESTIMATED COST OF RED SCHOOL DAM AND RESERVOIR

(Based on prices prevailing in Spring of 1956)

Elevation of crest of dam: 2,810 feet U.S.G.S. datum
Elevation of crest of spillway: 2,800 feet
Height of dam to spillway crest, above stream bed: 70 feet

Storage capacity of reservoir to spillway crest: 2,100 acre-feet
Discharge capacity of spillway with 5-foot freeboard: 1,500 second-feet

Item	Quantity	Unit price	Cost	
CAPITAL COSTS				
Dam				
Diversion and care of stream		lump sum	$5,000	
Stripping and preparation of foundation	38,900 cu.yd.	$1.00	38,900	
Embankment				
Impervious	245,000 cu.yd.	0.90	220,500	
Pervious	217,300 cu.yd.	2.50	543,300	
Grouting	2,400 lin.ft.	10.00	24,000	$831,700
Spillway				
Excavation	35,000 cu.yd.	2.50	87,500	
Backfill	5,600 cu.yd.	1.00	5,600	
Concrete	1,023 cu.yd.	60.00	61,400	
Reinforcing steel	76,700 lbs.	0.14	10,700	$165,200
Outlet Works				
Excavation	1,120 cu.yd.	2.50	2,800	
Concrete	600 cu.yd.	60.00	36,000	
Reinforcing steel	45,000 lbs.	.14	6,300	
Steel pipe, 78-inch diameter	108,000 lbs.	.30	32,400	
Slide gate, 5 feet x 5 feet	30,000 lbs.	.50	15,000	
Miscellaneous metal work	lump sum		9,000	$101,500
CAPITAL COSTS—Cont.				
Reservoir				
Land and improvements		lump sum	4,000	$4,000
Subtotal				$1,102,400
Administration and engineering, 10%				110,200
Contingencies, 15%				165,400
Interest during construction				24,100
TOTAL				$1,402,100
ANNUAL COSTS				
Interest, 3.5%				$49,100
Repayment, 0.76%				10,700
Replacement, 0.07%				1,000
General expense, 0.32%				4,500
Operation and maintenance				400
TOTAL				$65,700

TABLE F-11

ESTIMATED COST OF HIGHLAND DAM AND RESERVOIR

(Based on prices prevailing in Spring of 1956)

Elevation of crest of dam: 3,405 feet, U.S.G.S. datum
Elevation of spillway crest: 3,394 feet
Height of dam to spillway crest, above stream bed: 149 feet

Storage capacity of reservoir to spillway crest: 26,200 acre-feet
Discharge capacity of spillway with 6-foot freeboard: 4,500 second-feet

Item	Quantity	Unit price	Cost	
CAPITAL COSTS				
Dam				
Diversion and care of stream		lump sum	$20,000	
Stripping				
Rock	34,600 cu.yd.	$2.25	77,800	
Unclassified	80,700 cu.yd.	1.10	88,800	
Embankment				
Pervious	1,157,000 cu.yd.	1.90	2,198,300	
Impervious	615,000 cu.yd.	0.75	461,300	
Grouting	5,700 lin.ft.	7.50	42,800	$2,889,000
Spillway				
Excavation, rock used in dam	----	----	----	
Trimming and cleanup	13,100 sq.yd.	1.25	16,400	
Concrete	1,930 cu.yd.	35.00	67,600	
Reinforcing steel	161,000 lbs.	0.15	24,200	108,200
Outlet Works				
Excavation	540 cu.yd.	7.50	4,100	
Steel pipe	60,900 lbs.	0.30	18,300	
Concrete				
Encasement	415 cu.yd.	30.00	12,500	
Structural	225 cu.yd.	70.00	15,700	
Reinforcing steel	64,000 lbs.	0.15	9,600	
Trash rack steel	2,100 lbs.	0.30	600	
CAPITAL COSTS—Cont.				
High pressure-slide gate, 2 feet x 3 feet	12,500 lbs.	0.50	6,300	
Howell-Bunger valve, 30-inch diameter	12,300 lbs.	0.90	11,100	78,200
Reservoir				
Land and improvements		lump sum	81,000	
Public utilities		lump sum	26,000	
Clearing		lump sum	22,000	129,000
Subtotal				$3,204,400
Administration and engineering, 10%				312,500
Contingencies, 15%				468,700
Interest during construction				105,000
TOTAL				$4,091,600
ANNUAL COSTS				
Interest, 3.5%				$143,200
Repayment, 0.76%				31,100
Replacement, 0.07%				2,900
General expense, 0.32%				13,100
Operation and maintenance				5,100
TOTAL				$195,400

TABLE F-12

ESTIMATED COST OF CALLAHAN DAM AND RESERVOIR

(Based on prices prevailing in Spring of 1956)

Elevation of crest of dam: 3,366 feet, U.S.G.S. datum
Elevation of spillway crest: 3,355 feet
Height of dam to spillway crest above stream bed: 265 feet

Storage capacity of reservoir to spillway crest: 133,000 acre-feet
Discharge capacity of spillway with 5-foot freeboard: 12,900 second-feet

Item	Quantity	Unit price	Cost	
CAPITAL COSTS				
Dam				
Diversion tunnel, 12-foot diameter	1,700 lin. ft.	$360.00	$612,000	
Care of stream		lump sum	10,000	
Stripping, excavation and preparation of foundation	915,000 cu.yd.	1.25	1,143,800	
Grouting		lump sum	180,000	
Embankment				
Impervious	3,400,000 cu.yd.	.55	1,870,000	
Pervious	6,160,000 cu.yd.	.50	3,080,000	$6,895,800
Spillway				
Excavation	345,000 cu.yd.	1.50	517,500	
Concrete				
Weir	308 cu.yd.	35.00	10,800	
Walls	1,278 cu.yd.	60.00	76,700	
Slab	2,130 cu.yd.	30.00	63,900	
Reinforcing steel	278,800 lbs.	0.14	39,000	707,900
Outlet Works				
Steel pipe, 48-inch diameter	135,000 lbs.	0.30	40,500	
Concrete				
Tunnel plug	370 cu.yd.	30.00	11,100	
Intake structure	100 cu.yd.	100.00	10,000	
Reinforcing steel	10,000 lbs.	0.14	1,400	
CAPITAL COSTS—Cont.				
Butterfly valve, 48-inch diameter		lump sum	12,000	
Howell-Bunger valve, 48-inch diameter		lump sum	22,500	97,500
Reservoir				
Land and improvements		lump sum	294,000	
Public utilities		lump sum	90,000	
Clearing		lump sum	196,000	580,000
Subtotal				$8,281,200
Administration and engineering, 10%				828,100
Contingencies, 15%				1,242,200
Interest during construction				543,500
TOTAL				$10,895,000
ANNUAL COSTS				
Interest, 3.5%				$381,300
Repayment, 0.76%				82,800
Replacement, 0.07%				7,600
General expense, 0.32%				34,800
Operation and maintenance				15,000
TOTAL				$521,500

TABLE F-13

ESTIMATED COST OF GROUSE CREEK DAM AND RESERVOIR

(Based on prices prevailing in January, 1957)

Elevation of crest of dam: 3,675 feet, U.S.G.S. datum
Elevation of crest of spillway: 3,666 feet, U.S.G.S. datum
Elevation of stream bed: 3,500 feet
Height of dam to crest of spillway above stream bed: 166 feet
Storage capacity of reservoir to crest of spillway: 50,000 acre-feet
Discharge capacity of spillway with 4-foot freeboard: 6,000 second-feet

Item	Quantity	Unit price	Cost	
CAPITAL COSTS				
Dam				
Care and diversion of stream		lump sum	$10,000	
Stripping and preparation of foundation	240,925 cu.yd.	$1.59	383,000	
Embankment				
Impervious	1,578,016 cu.yd.	0.88	1,390,000	
Pervious	348,326 cu.yd.	1.13	394,000	
Riprap	48,333 cu.yd.	2.93	141,800	
Grouting		lump sum	50,000	
Miscellaneous items, 5%			118,200	$2,487,000
Spillway				
Excavation				
Overburden	36,016 cu.yd.	0.50	18,000	
Rock	86,200 cu.yd.	2.00	172,400	
Trimming and clean up	34,130 sq. ft.	0.08	2,730	
Concrete				
Walls	928 cu.yd.	75.00	69,700	
Bottom and Weir	957 cu.yd.	31.00	29,700	
Flip bucket	51 cu.yd.	50.00	2,550	
Reinforcing steel	193,600 lbs.	0.20	38,720	
Miscellaneous items, 10%			33,200	367,000
Outlet Works				
Excavation	6,380 cu.yd.	3.00	19,100	
Backfill	5,640 cu.yd.	1.00	5,600	
Steel pipe, 42-inch diameter	85,280 lbs.	0.40	34,100	
Concrete				
Pipe cover	444 cu.yd.	40.00	17,800	
Structural	171 cu.yd.	75.00	12,800	
Reinforcing steel	12,825 lbs.	0.20	2,600	
Trashrack		lump sum	2,000	
CAPITAL COSTS—Cont.				
Slide gate, 36-inch diameter		lump sum	$2,000	
Howell-Bunger valve, 18-inch diameter		lump sum	3,000	
Miscellaneous items, 15%			14,900	$113,900
Reservoir				
Land	800 acres	$50.00	40,000	
Improvements		lump sum	20,000	
Clearing	800 acres	25.00	20,000	
Roads	4 miles	15,000.00	60,000	
Public Utilities		lump sum	5,000	145,000
Subtotal				$3,112,900
Geological investigations, 5%				155,700
Administration and engineering, 10%				311,300
Contingencies, 15%				467,000
Interest during construction				82,600
TOTAL				$4,129,500
ANNUAL COSTS				
Interest, 3.5%				$144,500
Repayment, 0.76%				31,400
Replacement, 0.07%				2,900
General expense, 0.32%				13,200
Operation and maintenance				7,500
TOTAL				$199,500

TABLE F-14

ESTIMATED COST OF ETNA DAM AND RESERVOIR

(Based on prices prevailing in January, 1957)

Elevation of crest of dam: 2,942 feet, U.S.G.S. datum
Elevation of crest of spillway: 2,932 feet
Elevation of stream bed: 2,855 feet
Height of dam to crest of spillway above stream bed: 77 feet

Storage capacity of reservoir to crest of spillway: 12,000 acre-feet
Discharge capacity of spillway with 4-foot freeboard: 12,500 second-feet

Item	Quantity	Unit price	Cost	
CAPITAL COSTS				
Dam				
Diversion and care of stream		lump sum	$10,000	
Stripping and preparation of foundation	187,256 cu.yd.	$1.00	187,300	
Embankment				
Impervious	823,217 cu.yd.	0.74	609,000	
Pervious	173,258 cu.yd.	0.53	91,800	
Riprap	43,403 cu.yd.	2.62	113,800	
Grouting		lump sum	25,000	
Miscellaneous items		lump sum	51,800	$1,088,700
Spillway				
Excavation, unclassified	41,812 cu.yd.	0.95	39,700	
Excavation, rock	157,910 cu.yd.	2.00	315,800	
Concrete				
Walls	1,317 cu.yd.	41.00	54,000	
Bottom	2,741 cu.yd.	31.00	85,000	
Weir	240 cu.yd.	35.00	8,400	
Reinforcing steel	429,800 lbs.	0.20	86,000	
Miscellaneous items		lump sum	58,900	647,800
Outlet Works				
Excavation	3,098 cu.yd.	3.00	9,300	
Concrete				
Pipe cover	236 cu.yd.	31.00	7,300	
Structural	191 cu.yd.	100.00	19,100	
Welded steel pipe, 42-inch diameter	47,012 lbs.	0.32	15,000	
High pressure slide gate, 42-inch diameter		lump sum	8,000	
Howell-Bunger valve, 32-inch diameter		lump sum	14,000	
CAPITAL COSTS—Cont.				
Trashrack		lump sum	$2,000	
Reinforcing steel	80,000 lb.	$0.20	16,000	
Riprap	164 cu.yd.	4.00	700	
Miscellaneous items		lump sum	13,700	$105,100
Reservoir				
Land	295 acres	100.00	$29,500	
Improvements		lump sum	50,000	
Clearing	295 acres	50.00	14,300	
Roads		lump sum	40,000	
Public utilities		lump sum	15,000	$148,800
Subtotal				$1,990,400
Geologic investigations, 5%				99,500
Administration and engineering, 10%				199,000
Contingencies, 15%				298,600
Interest during construction				52,800
TOTAL				$2,640,300
ANNUAL COSTS				
Interest, 3.5%				$92,400
Repayment, 0.76%				20,100
Replacement, 0.07%				1,800
Operation and maintenance				2,400
General expense, 0.32%				8,400
TOTAL				$125,100

TABLE F-15

ESTIMATED COST OF SHACKLEFORD CREEK DIVERSION INTO MUGGINSVILLE RESERVOIR

(Based on prices prevailing in January, 1957)

Item	Quantity	Unit price	Cost	
CAPITAL COSTS				
Diversion Dam				
Strip and prepare site		lump sum	$2,000	
Excavation	300 cu.yd.	4.00	1,200	
Concrete	350 cu.yd.	75.00	26,200	
Reinforcing steel	35,000 lbs.	0.15	5,250	
Flashboards, timber	2.8 MBM	300.00	840	
Deck and railing	3.0 MBM	450.00	1,350	
Appurtenances		lump sum	3,500	$40,340
Diversion Canal				
Excavation	9,200 cu.yd.	3.00	27,600	
Embankment	7,400 cu.yd.	0.60	4,500	
Trimming	16,600 sq.yd.	0.75	12,500	
Lining	1,900 cu.yd.	42.10	80,000	
Miscellaneous items		lump sum	12,460	137,060
Subtotal				$177,400
CAPITAL COSTS—Cont.				
Geological investigations, 5%				$8,900
Administration and engineering, 10%				17,700
Contingencies, 15%				26,600
Interest during construction				4,700
TOTAL				$235,300
ANNUAL COSTS				
Interest, 3.5%				$8,200
Repayment, 0.76%				1,800
Replacement, 0.07%				200
Operation and maintenance				2,400
TOTAL				$12,600

TABLE F-16

ESTIMATED COST OF MUGGINSVILLE DAM AND RESERVOIR AND ORO-FINO PROJECT

(Based on prices prevailing in January, 1957)

Elevation of crest of dam: 2,956 feet, U.S.G.S. datum
Elevation of crest of spillway: 2,946 feet
Elevation of stream bed: 2,853 feet
Height of dam to crest of spillway above stream bed: 93 feet

Storage capacity of reservoir to crest of spillway: 23,000 acre-feet
Discharge capacity of spillway with 6-foot freeboard: 6,000 second-feet

Item	Quantity	Unit price	Cost	
CAPITAL COSTS				
Dam				
Diversion and care of stream		lump sum	$5,000	
Excavation				
Overburden	126,160 cu.yd.	1.00	120,200	
Cutoff trench, unclassified	93,420 cu.yd.	2.00	186,800	
Cutoff trench, rock	10,380 cu.yd.	5.00	51,900	
Embankment				
Impervious	2,243,000 cu.yd.	0.71	1,595,000	
Pervious	535,900 cu.yd.	0.88	472,000	
Riprap, spillway salvage	131,720 cu.yd.	2.30	303,000	
Grouting		lump sum	50,000	
Miscellaneous items		lump sum	139,100	$2,929,000
Spillway				
Excavation				
Overburden	55,059 cu.yd.	0.50	27,600	
Rock	312,031 cu.yd.	2.00	624,100	
Channel	79,538 cu.yd.	0.70	55,600	
Trimming and clean up	68,200 sq.ft.	0.08	5,500	
Concrete				
Walls	1,054 cu.yd.	41.00	43,200	
Bottom	1,471 cu.yd.	31.00	45,600	
Weir	140 cu.yd.	35.00	4,900	
Reinforcing steel	200,000 lbs.	0.20	40,000	
Miscellaneous items, 10%		lump sum	13,500	860,000
Outlet Works				
Excavation	1,260 cu.yd.	3.00	3,800	
Welded steel pipe, 42-inch diameter	120,000 lbs.	0.30	36,000	
Concrete	770 cu.yd.	40.00	30,800	
Reinforcing steel	57,000 lbs.	0.15	8,500	
Submerged inlet and trashracks		lump sum	2,000	
Slide gate, 36-inch diameter		lump sum	2,000	
Howell-Bunger valve, 18-inch diameter		lump sum	3,000	
Miscellaneous items, 15%		lump sum	12,900	99,000
Pumping Plant				
3,000 gpm unit, pump, motor and electrical equipment	3 ea.	9,900.00	29,700	
1,500 gpm unit, pump, motor and electrical equipment	1 ea.	8,400.00	8,400	
Discharge penstock, 24-inch diameter	32,000 lbs.	0.30	9,600	
CAPITAL COSTS—Cont.				
Gate valves, 12 and 14-inch diameter	8 ea.	500.00	$4,000	
Check valves, 12-inch diameter	4 ea.	800.00	3,200	
Miscellaneous piping	7,500 lbs.	0.30	2,300	
Outdoor installation base, and crane		lump sum	8,500	
Miscellaneous items		lump sum	6,600	$72,300
Oro-Fino Canal				
Excavation	10,300 cu.yd.	3.00	30,900	
Embankment	6,300 cu.yd.	0.60	3,800	
Trimming	7,800 sq.yd.	0.75	5,900	
Lining	650 cu.yd.	42.00	27,300	
Miscellaneous items, 10%		lump sum	6,800	74,700
Oro-Fino Tunnel				
7-foot diameter horseshoe concrete lined	2,600 lin.ft.	181.00	470,600	
Miscellaneous items		lump sum	47,100	517,700
Reservoir				
Land	750 acres	100.00	75,000	
Public Utilities	4 miles	5,000.00	20,000	
Clearing	750 acres	25.00	18,800	
Improvements, dwellings	20 each	5,000.00	100,000	
Highway relocation	5 miles	25,000.00	125,000	338,800
Subtotal				$4,891,500
Geological investigations, 5%				244,600
Administration and engineering, 10%				489,200
Contingencies, 15%				733,800
Interest during construction				130,000
TOTAL				$6,489,100
ANNUAL COSTS				
Interest, 3.5%				$227,100
Repayment, 0.76%				49,300
Replacement, 0.07%				4,500
General expense, 0.32%				20,800
Operation and maintenance				4,400
Electrical energy				4,700
Shackleford Creek Diversion				12,600
TOTAL				$323,400

TABLE F-17

ESTIMATED COST OF LAYMAN DAM AND RESERVOIR

(Based on prices prevailing in Spring of 1956)

Elevation of crest of dam: 2,650 feet, U.S.G.S. datum
Elevation to crest of spillway: 2,638 feet
Height of dam to crest of spillway above stream bed: 148 feet
Storage capacity of reservoir to crest of spillway: 21,500 acre-feet
Discharge capacity of spillway with 5-foot freeboard: 10,000 second-feet

Item	Quantity	Unit price	Cost	
CAPITAL COSTS				
Dam				
Diversion and care of stream		lump sum	$5,000	
6-foot diameter diversion tunnel	750 lin.ft.	176.00	132,000	
Stripping and preparation of foundation	97,300 cu.yd.	2.00	194,600	
Embankment				
Impervious	521,800 cu.yd.	0.90	469,600	
Pervious	687,400 cu.yd.	1.30	893,600	
Grouting		lump sum	52,000	$1,746,800
Spillway				
Excavation	34,700 cu.yd.	4.00	138,800	
Concrete				
Weir and slab	1,440 cu.yd.	35.00	50,400	
Walls	4,100 cu.yd.	60.00	246,000	
Reinforcing steel	484,000 lbs.	0.14	67,800	503,000
Outlet Works				
36-inch diameter welded steel pipe	58,500 lbs.	0.30	17,600	
Trash rack steel	2,100 lbs.	0.30	600	
Slide gate, 36-inch diameter	20,000 lbs.	0.50	10,000	
Regulating valve, 36-inch diameter	16,000 lbs.	0.90	14,400	
CAPITAL COSTS—Cont.				
Concrete, structural	200 cu.yd.	100.00	20,000	
Reinforcing steel	20,000 lbs.	0.14	2,800	65,400
Reservoir				
Land and improvements		lump sum	45,000	
Public utilities		lump sum	156,000	
Clearing and timber		lump sum	70,000	271,000
Subtotal				$2,586,200
Administration and engineering, 10%				258,600
Contingencies, 15%				387,900
Interest during construction				113,000
TOTAL				$3,345,700
ANNUAL COSTS				
Interest, 3.5%				117,100
Repayment, 0.76%				25,400
Replacement, 0.07%				2,300
General expense, 0.32%				10,700
Operation and maintenance				4,700
TOTAL				$160,200

TABLE F-18

ESTIMATED COST OF MOREHOUSE DAM AND RESERVOIR

(Based on prices prevailing in Spring of 1956)

Elevation of crest of dam: 1,545 feet, U.S.G.S. datum
Elevation of spillway crest: 1,530 feet
Height of dam to spillway crest above stream bed: 560 feet

Storage capacity of reservoir to spillway crest: 910,000 acre-feet
Discharge capacity of spillway with 5-foot freeboard: 55,000 second-feet

Item	Quantity	Unit price	Cost	
CAPITAL COSTS				
Dam				
Diversion and care of stream		lump sum	$50,000	
Tunnel, 29-foot diameter, circular	2,640 lin.ft.	1,170.00	3,088,800	
Stripping and preparation of foundation	267,600 cu.yd.	3.00	802,800	
Cutoff excavation	116,500 cu.yd.	7.00	815,500	
Grouting and cutoff		lump sum	340,000	
Embankment				
Impervious	1,160,000 cu.yd.	1.50	1,740,000	
Transition	1,632,000 cu.yd.	2.00	3,264,000	
Pervious	13,592,000 cu.yd.	1.60	21,747,200	$31,848,300
Spillway				
Excavation, rock used in dam	----	----	----	
Trimming and cleanup	8,500 cu.yd.	1.00	8,500	
Concrete	1,660 cu.yd.	35.00	58,100	
Reinforcing steel	83,000 lbs.	0.15	12,400	79,000
Outlet Works				
Concrete				
Structural	900 cu.yd.	100.00	90,000	
Tunnel plug	1,210 cu.yd.	50.00	60,500	
Reinforcing steel	90,000 lbs.	0.15	13,500	
Trash rack, steel	20,000 lbs.	0.30	6,000	
Welded steel pipe, 12-foot diameter	730 lin. ft.	650.00	474,500	
CAPITAL COSTS—Cont.				
Butterfly valve, 12-foot diameter		lump sum	90,000	734,500
Reservoir				
Land and improvements		lump sum	500,000	
Public utilities		lump sum	800,000	
Clearing		lump sum	500,000	1,800,000
Subtotal				$34,469,800
Administration and engineering, 10%				3,446,200
Contingencies, 15%				5,169,300
Interest during construction				3,015,400
TOTAL				$46,093,000
ANNUAL COSTS				
Interest, 3.5%				$1,613,200
Repayment, 0.76%				350,300
Replacement, 0.07%				32,300
General expense, 0.32%				147,500
Operation and maintenance				60,000
TOTAL				$2,203,300

TABLE F-19

ESTIMATED COST OF MOREHOUSE POWER PLANT

(Based on prices prevailing in Spring of 1956)

Installed capacity of power plant: 90,000 kilowatts

Dependable capacity of power plant: 80,000 kilowatts

Item	Quantity	Unit price	Cost
CAPITAL COST			
Power Plant			
90,000 kilowatt, single unit		lump sum	$6,840,000
Subtotal			$6,840,000
Administration and engineering, 10%			684,000
Contingencies, 15%			1,026,000
Interest during construction			299,000
TOTAL			$8,849,000
ANNUAL COSTS			
Interest, 3.5%			$309,700
Repayment, 0.76%			67,300
Replacement, 1.20%			106,200
General expense, 0.32%			28,300
Insurance, 0.12%			10,600
Operation and maintenance			321,000
TOTAL			$843,100

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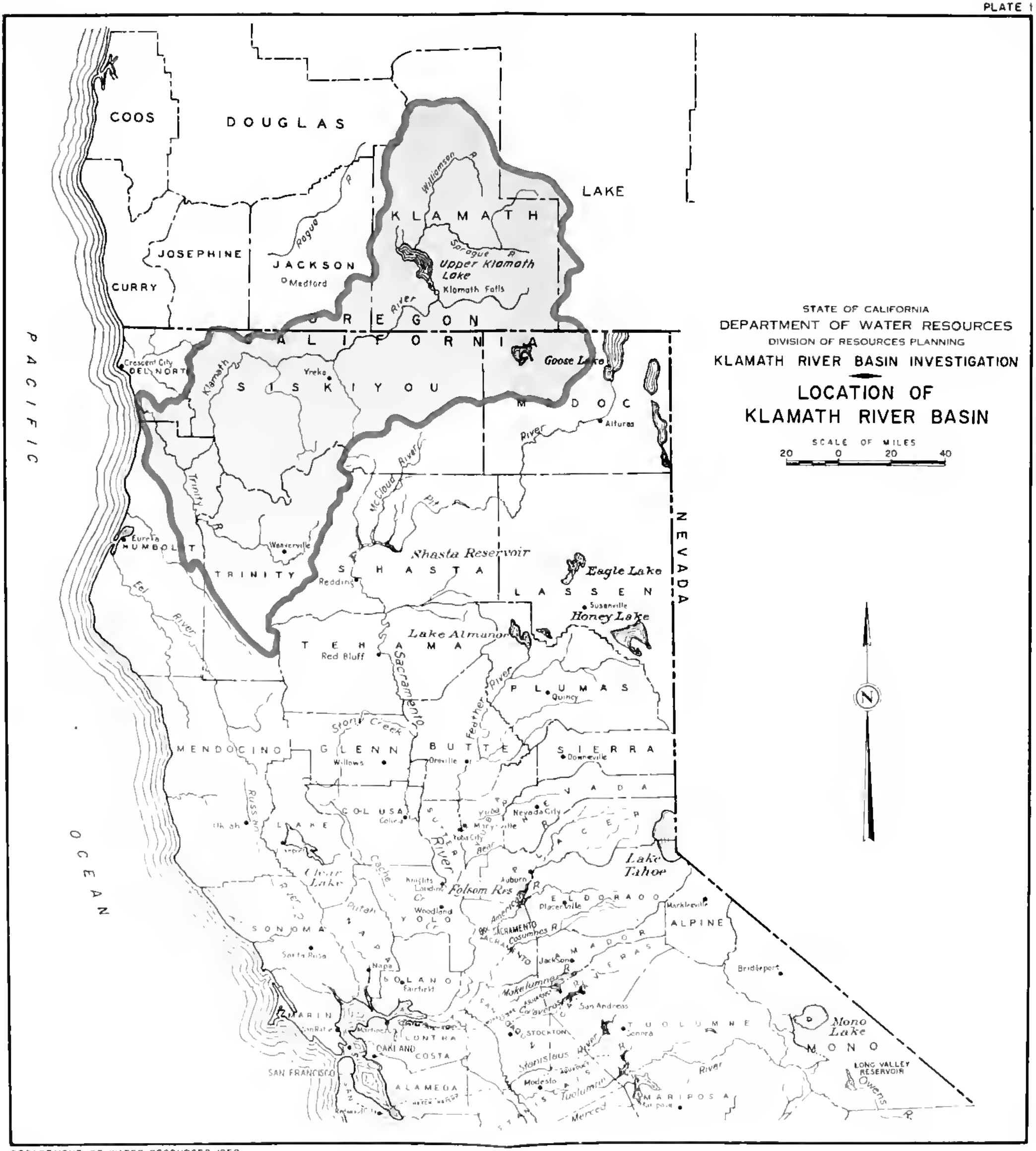
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
KLAMATH RIVER BASIN INVESTIGATION
LOCATION OF
KLAMATH RIVER BASIN
SCALE OF MILES
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N
PACIFIC
OCEAN
COOS
DOUGLAS
LAKE
KLAMATH
JOSEPHINE
JACKSON
CURRY
Medford
Upper Klamath Lake
Klamath Falls
Williamson R
Sprague R
Rogue R
Klamath River
OREGON
CALIFORNIA
Crescent City
DEL NORTE
SISKIYOU
Yreka
Goose Lake
MODOC
Alturas
Pit River
McCloud River
Trinity R
Eureka
HUMBOLDT
Weaverville
TRINITY
SHASTA
Redding
Shasta Reservoir
Eagle Lake
LASSEN
Susanville
Honey Lake
NEVADA
Eel River
Lake Almanor
TEHAMA
Red Bluff
Sacramento
PLUMAS
Quincy
Feather River
MENDOCINO
GLENN
Willows
Stony Creek
BUTTE
Oroville
SIERRA
Downieville
COLUSA
Colusa
NEVADA
Nevada City
Marysville
Yuba City
Yuba R
Bear R
PLACER
Lake Tahoe
Clear Lake
LAKE
Cache
Putah
Knights Landing
Woodland
YOLO
Folsom Res
Auburn
EL DORADO
Placerville
Markleeville
ALPINE
SONOMA
Santa Rosa
NAPA
Napa
SACRAMENTO
American R
Cosumnes R
AMADOR
Jackson
CALAVERAS
Bridgeport
SOLANO
Fairfield
Mokelumne R
Calaveras R
San Andreas
MARIN
Martinez
CONTRA COSTA
OAKLAND
SAN FRANCISCO
ALAMEDA
STOCKTON
SAN JOAQUIN
Stanislaus River
TUOLUMNE
Sonora
Mono Lake
MONO
LONG VALLEY RESERVOIR
Owens R
Modesto
Tuolumne
Merced
MARIPOSA
STANISLAUS

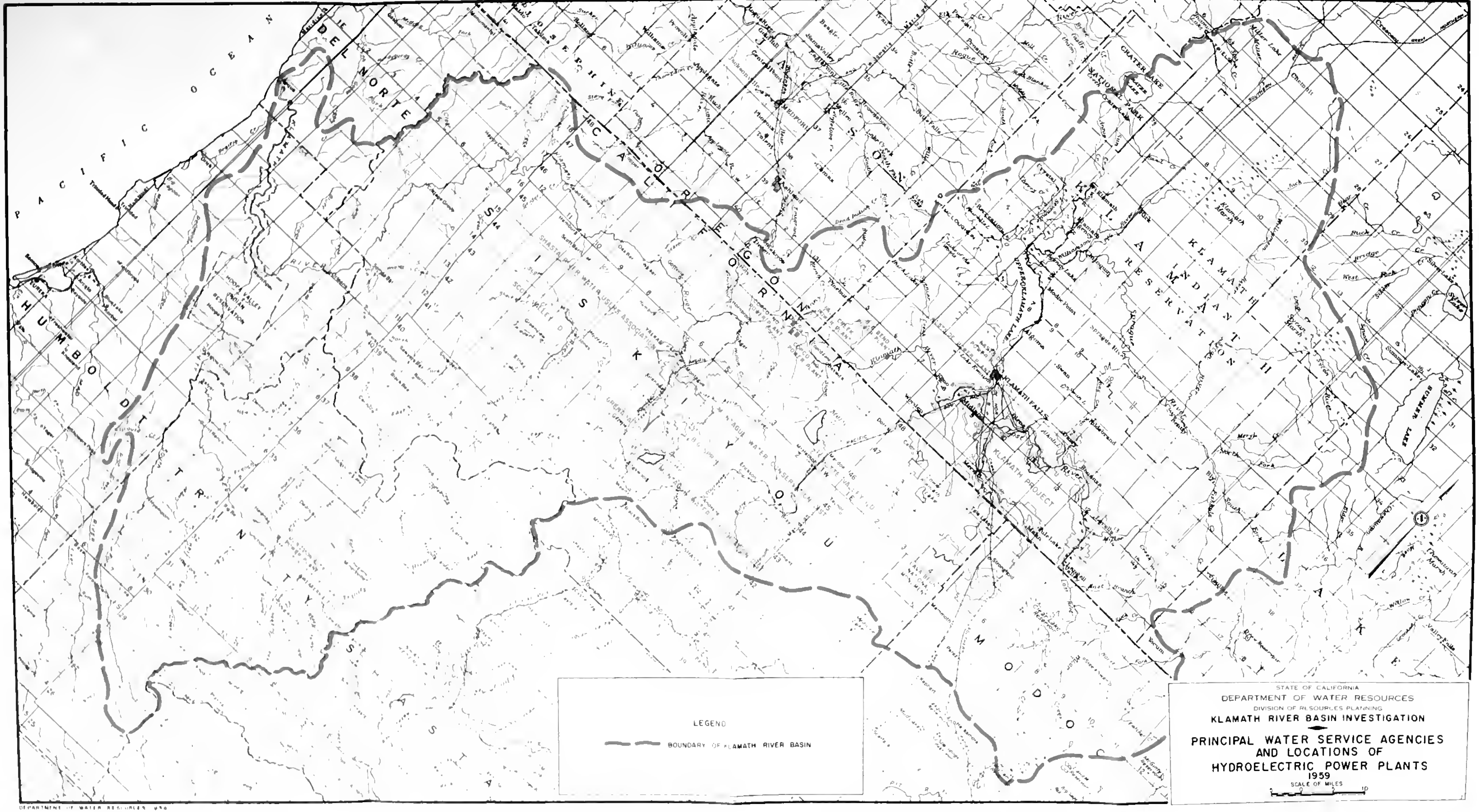
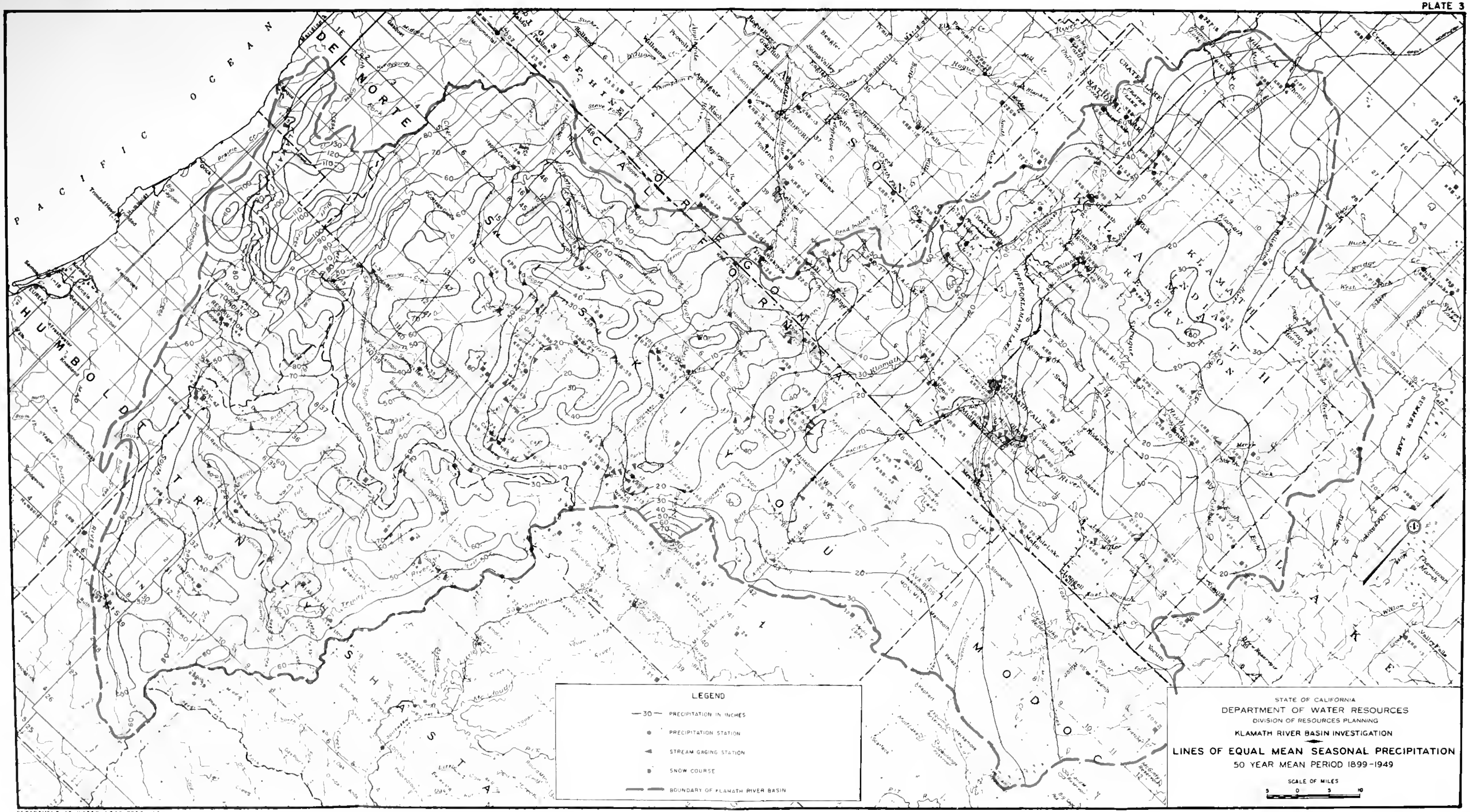
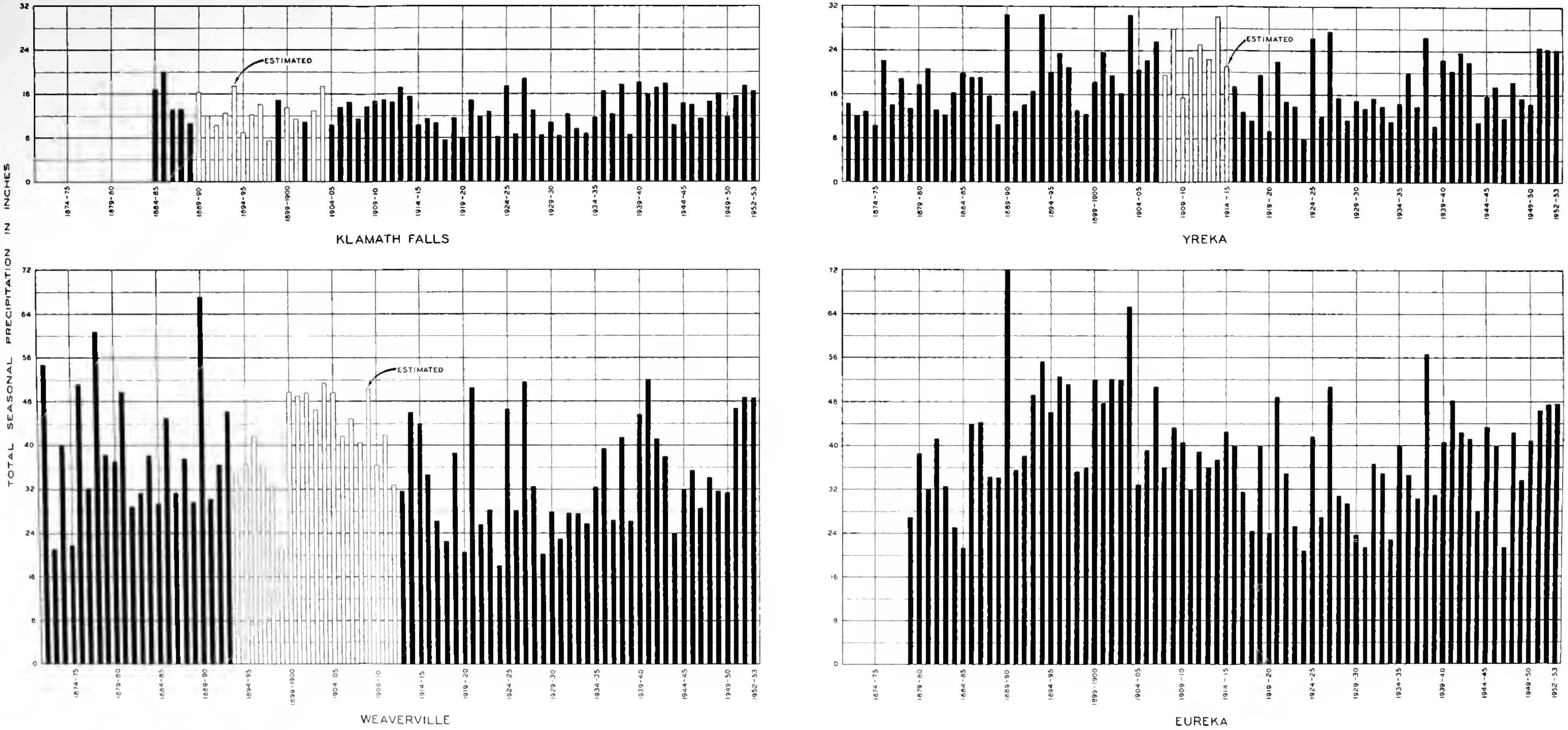

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
KLAMATH RIVER BASIN INVESTIGATION
PRINCIPAL WATER SERVICE AGENCIES AND LOCATIONS OF HYDROELECTRIC POWER PLANTS
1959
SCALE OF MILES
LEGEND
BOUNDARY OF KLAMATH RIVER BASIN
PACIFIC OCEAN
DEL NORTE
HUMBOLDT
TRINITY
SISKIYOU
SHASTA
MODOC
LAKE
KLAMATH
JACKSON
JOSEPHINE
CALIFORNIA
OREGON
CRATER LAKE NATIONAL PARK
KLAMATH INDIAN RESERVATION
KLAMATH FALLS
MEDFORD
KLAMATH PROJECT
UPPER KLAMATH LAKE
SUMMER LAKE
SCOTT VALLEY I.D.
SHASTA RIVER WATER USERS ASSOCIATION
HOOPA VALLEY INDIAN RESERVATION
DEPARTMENT OF WATER RESOURCES 1959

PLATE 3

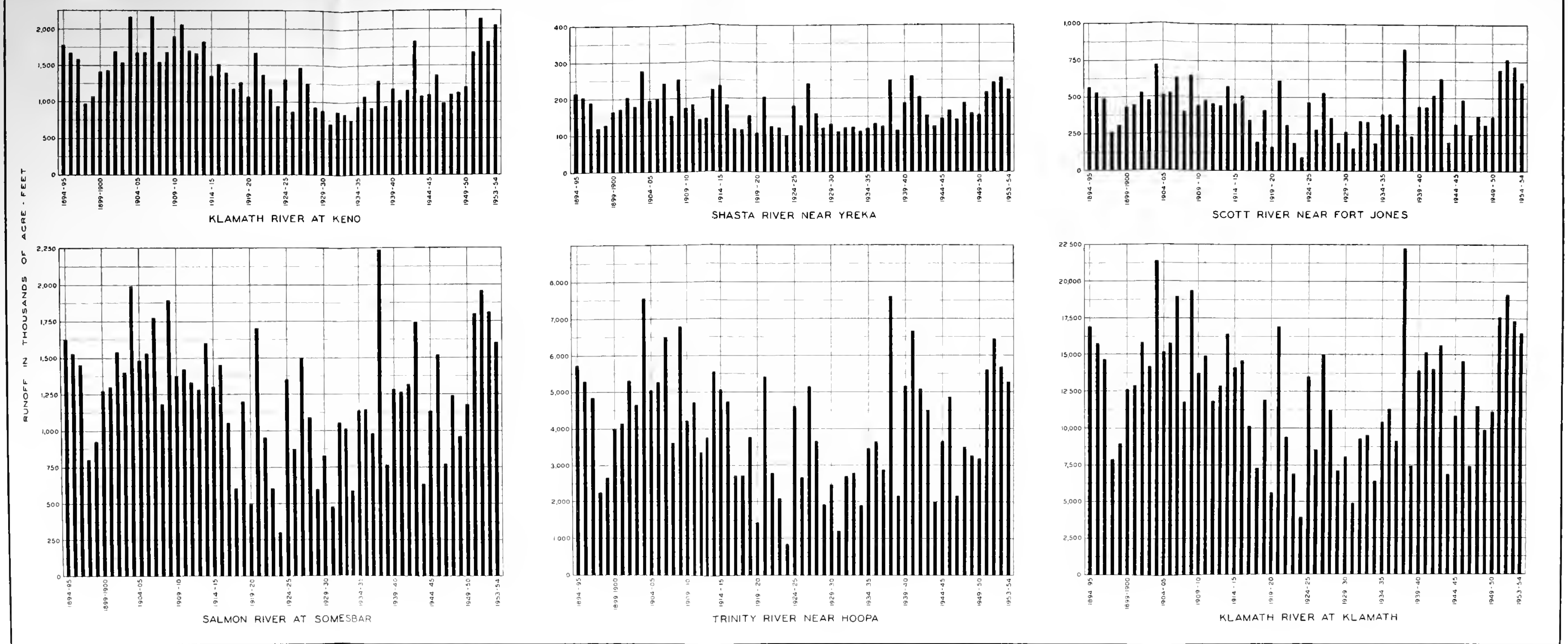


DEPARTMENT OF WATER RESOURCES 1959

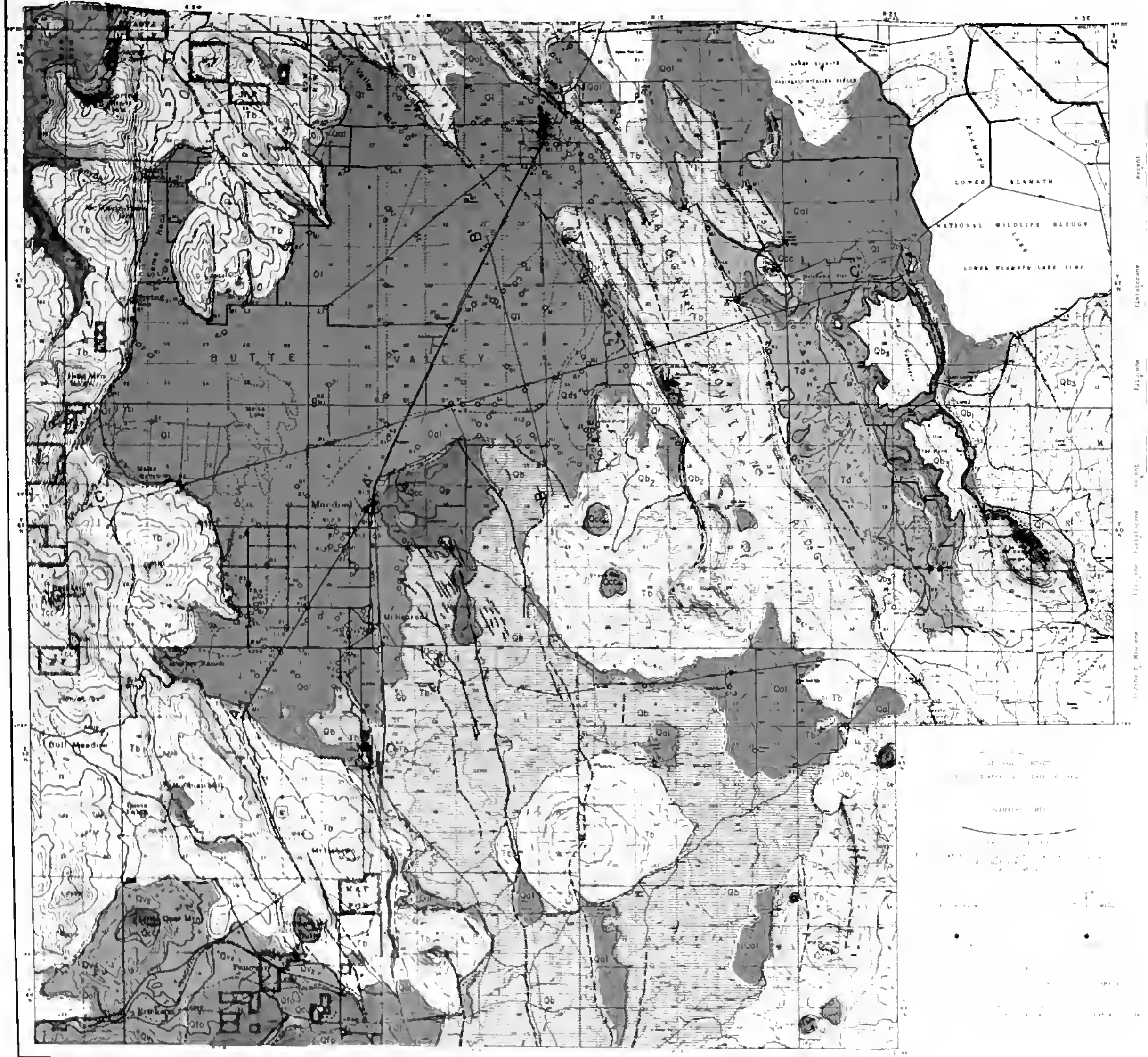
PLATE 4



RECORDED AND ESTIMATED SEASONAL PRECIPITATION AT SELECTED STATIONS IN THE KLAMATH RIVER BASIN



ESTIMATED SEASONAL NATURAL RUNOFF AT SELECTED STATIONS IN THE KLAMATH RIVER BASIN



EXPLANATION

SEDIMENTARY ROCKS

Qds — DUNE SAND
Unconsolidated sand, in part actively drifting. Generally above the saturated zone.

Qt — TALUS
Wedge-shaped deposits of blocky debris at the base of steep fault scarps. Highly permeable. May serve as ground water intake areas, storage reservoirs, or drains.

Qf — ALLUVIAL-FAN DEPOSITS
Unconsolidated deposits consisting of poorly sorted boulders, gravel, sand, and silt beneath alluvial fans, also includes remnants of older alluvial-fan deposits. Generally poorly permeable but transmits water to underlying formations.

Qal — ALLUVIUM
Includes sand, gravel, and clay in the eastern and southern parts of Butte Valley, poorly sorted alluvial deposits collected in relatively shallow basins or depressions, local playa deposits, and gravel and sand in major stream channels. Moderately permeable but generally above the saturated zone.

Ql — LAKE DEPOSITS
Poorly consolidated clay, volcanic ash, diatomite, and sand with local stringers of gravelly sand. Locally interfingers with and is overlain by talus, alluvium, and alluvium and alluvial-fan deposits. In general poorly permeable. Moderately permeable along the east side of Butte Valley, where tapped by irrigation wells.

Qfo — FLUVIOGLACIAL DEPOSITS
Unstratified rounded to angular fragments and boulders in a matrix of sand, clay, and silt. Probably poorly permeable, not tapped by wells.

Qm — GLACIAL MORAINES
Unstratified bouldery deposits in a clayey matrix. Not tapped by wells, believed to be poorly permeable.

Td — DIATOMITE
Massive-appearing gray to white diatomite. Locally contains interbedded sand, cindery tuff-breccia, and volcanic ash. Diatomite essentially not water bearing, some water obtained from the interbedded clastic deposits.

IGNEOUS ROCKS

Qv1, Qv2, Qv3, Qvc — LATER VOLCANIC ROCKS OF THE HIGH CASCADES
Qv1 Hypersthene-rich andesitic flows of Deer Mountain. Qv2 Black vesicular olivine-augite basalt flows of Little Deer Mountain. Qv3 Black vesicular olivine basalt in Butte Creek Canyon. Qvc Related cinder cones. Highly permeable. Serve chiefly as recharge media.

Qb — BUTTE VALLEY BASALT
Gray, vesicular olivine basalt. Highly permeable, yields large supplies of water to wells in the Macdoel-Mount Hebron area.

Qb1, Qb2, Qb3, Qbc — BASALTIC LAVA FLOWS
Qb1 Dark colored basalt flows near Sharp Mountain. Qb2 Coarsely vesicular black aphanitic basalt near Sheep Mountain. Qb3 Gray vesicular olivine basalt flows on Big and Little Tablelands and extensive basalt flows south of Lower Klamath Lake. Qbc Associated cinder cones. Generally very permeable, important chiefly as intake areas for ground water recharge.

Qp — PYROCLASTIC ROCKS
Well consolidated massive to thin bedded lapilli tuff and tuff breccia. Moderately permeable, locally yields water to stock wells.

Tb, Tbc — VOLCANIC ROCKS OF THE HIGH CASCADES
Tb Plain-gray olivine basalt and basaltic andesite and discontinuous layers of yellowish tuff and tuff breccia. Tbc Related scoria mounds. Very permeable, important chiefly as a ground water storage reservoir.

Major Unconformity

Tea — VOLCANIC ROCKS OF THE WESTERN CASCADES
Chiefly andesitic lava flows and lesser amounts of andesitic tuff-breccia and lapilli tuff. Probably poorly permeable, not tapped by wells.

QUATERNARY — Recent, Pleistocene; TERTIARY — Pliocene; QUATERNARY — Recent, Pleistocene; TERTIARY — Pliocene and Miocene

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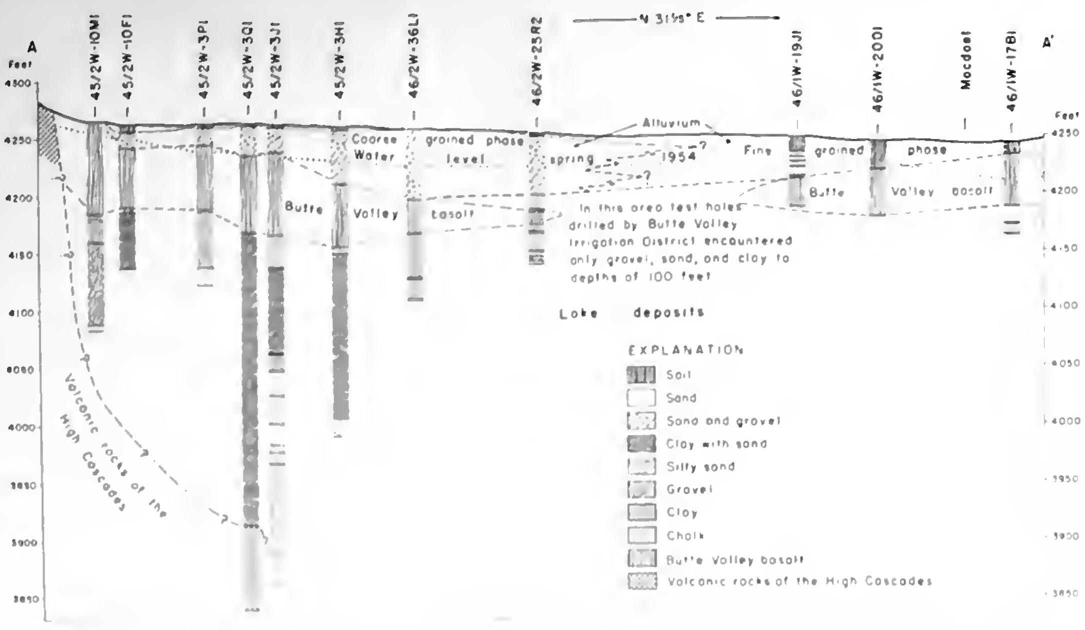
KLAMATH RIVER BASIN INVESTIGATION

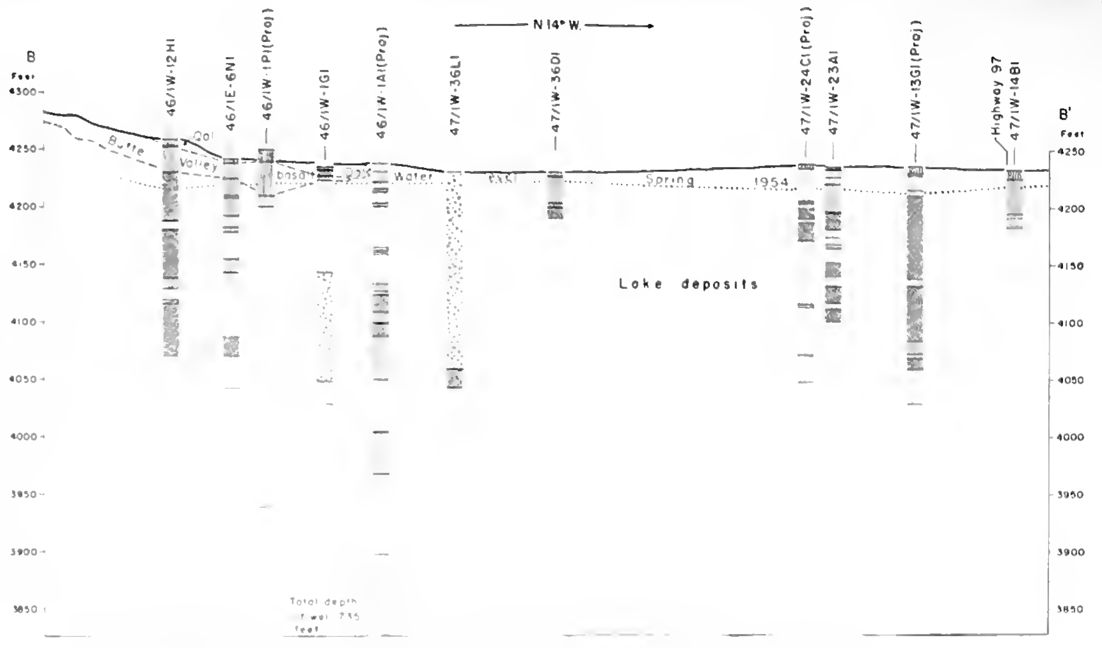
GEOLOGIC MAP OF BUTTE VALLEY

1959

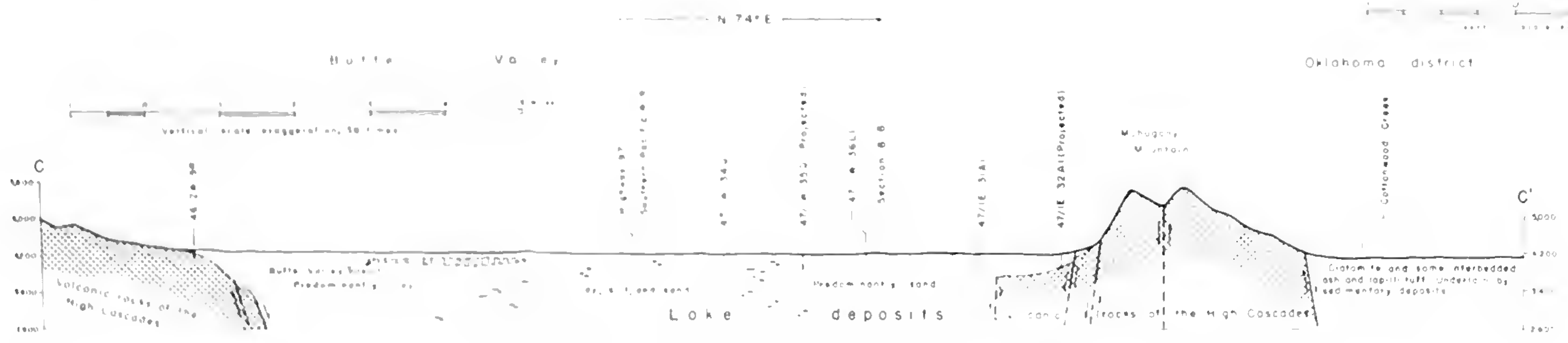
SCALE OF MILES



GEOLOGIC SECTION A-A IN BUTTE VALLEY



GEOLOGIC SECTION B-B IN BUTTE VALLEY

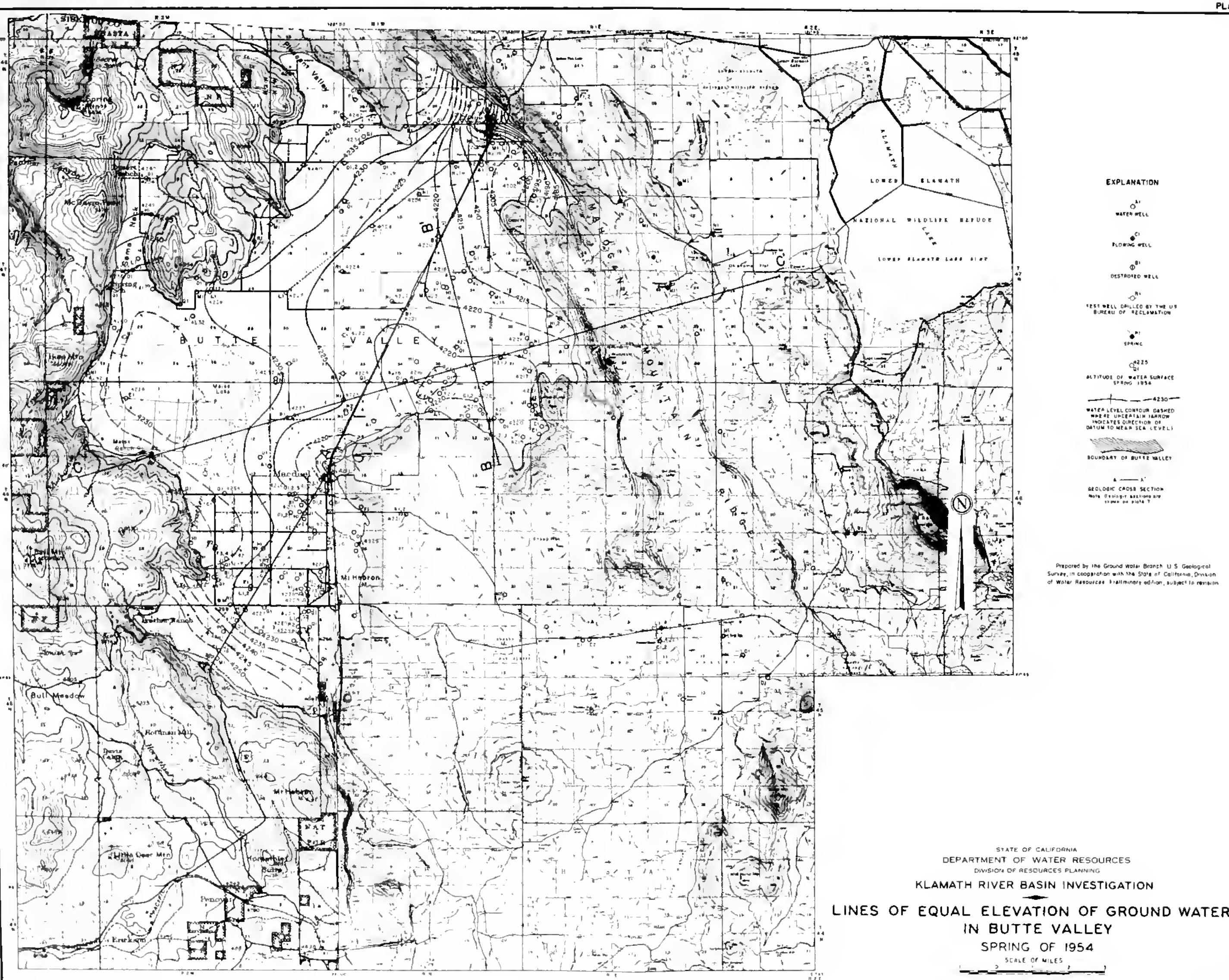


GEOL... SECTION C-C' ACROSS BUTTE VALLEY REGION

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
KLAMATH RIVER BASIN INVESTIGATION

GEOLOGIC SECTIONS OF BUTTE VALLEY

1959



STATE OF CALIFORNIA
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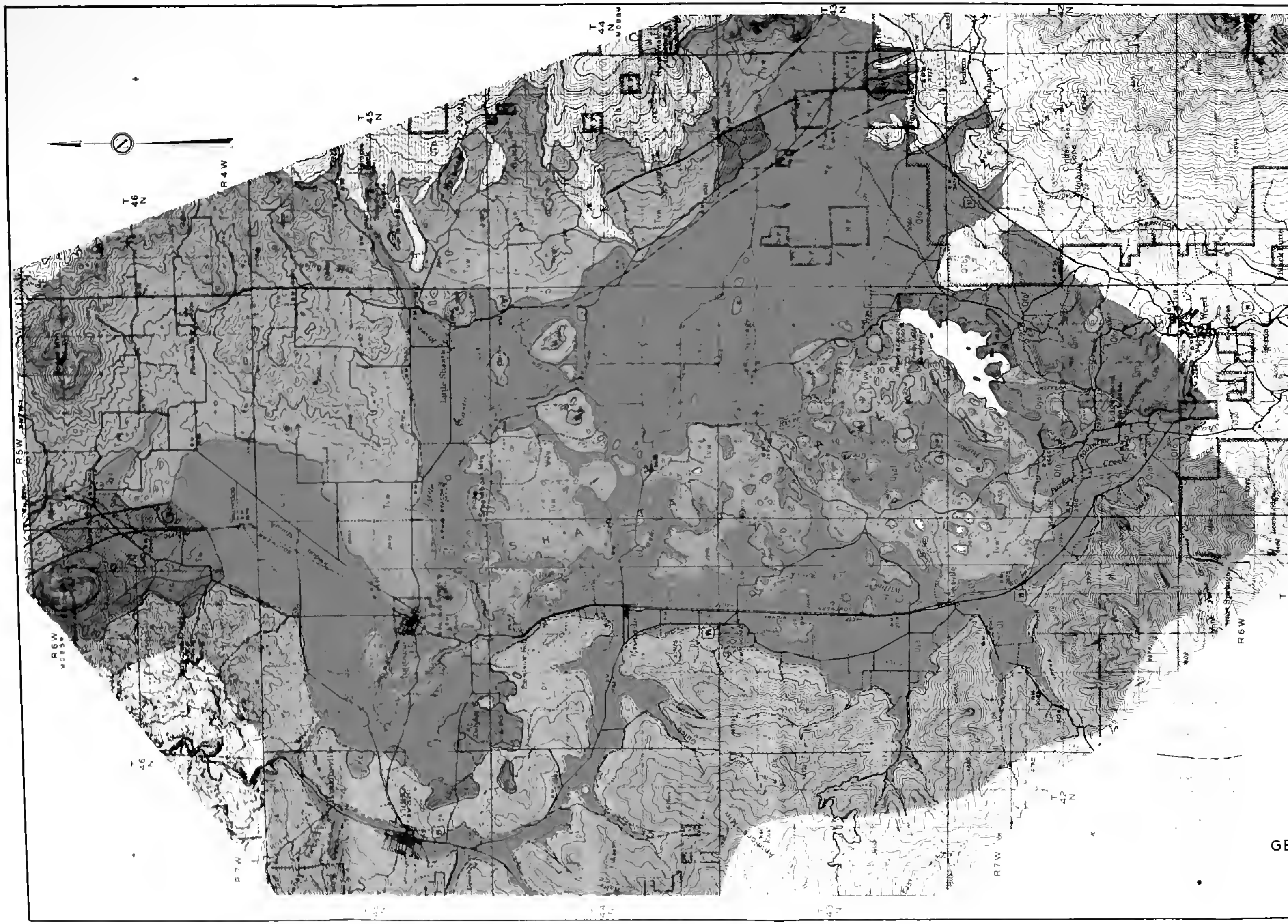
DIVISION OF RESOURCES PLANNING

KLAMATH RIVER BASIN INVESTIGATION

LINES OF EQUAL ELEVATION OF GROUND WATER IN BUTTE VALLEY

SPRING OF 1954



EXPLANATION

UNCONSOLIDATED ROCKS

Qya YOUNGER ALLUVIUM

(Stream channel, flood-plain, and fan deposits, consisting of lenses of permeable sand and gravel in a clay matrix. Yields water for domestic, stock, and irrigation supplies)

Qoa OLDER ALLUVIUM

(Poorly sorted boulders, sand, and gravel in a clay matrix. Generally yields water sufficient for domestic and stock supplies).

Qfg FLUVIOGLACIAL DEPOSITS

(Unstratified to poorly stratified bouldery deposits in a fine-grained matrix. Yield water for domestic, stock, and irrigation supplies at south end of Shasta Valley).

Qm MORAINAL DEPOSITS

(Unstratified bouldery deposits in a fine-grained matrix. Yield water for domestic, stock, and irrigation supplies at south end of Shasta Valley).

Qt TERRACE DEPOSITS

(Gravel and sandy clay, of limited extent, position generally above the water table).

QUATERNARY

CONSOLIDATED ROCKS

[illegible] CAVE BASAL

[illegible]

QTb [illegible] OF THE HIGH CASCADE

[illegible]

Tew [illegible] OF THE WESTERN CASCADE

[illegible]

Tu [illegible] FORMATION

[illegible]

Kc [illegible] FORMATION

[illegible]

pK [illegible]

[illegible]

TERTIARY

CRETACEOUS

PRE-CRETACEOUS

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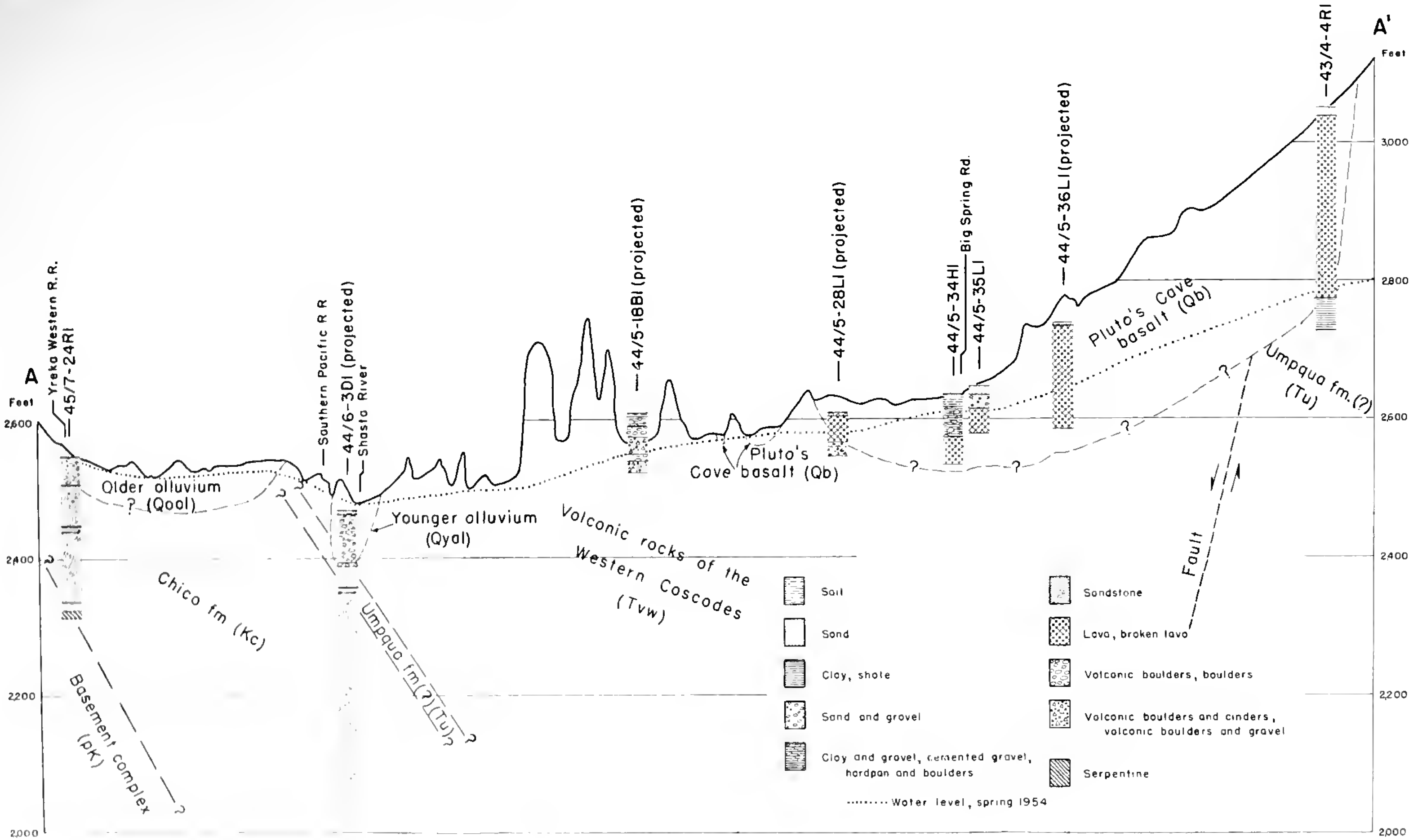
KLAMATH RIVER BASIN INVESTIGATION

GEOLOGIC MAP OF SHASTA VALLEY

1959

SCALE OF MILES



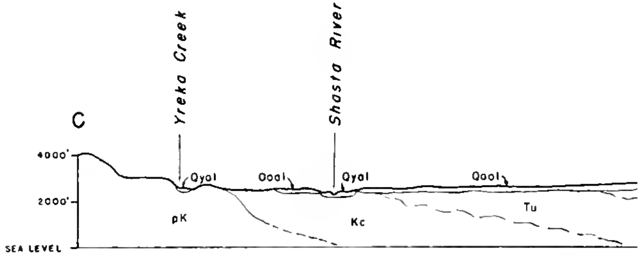
GEOLOGIC SECTION A-A'

0 1 2 3 4 5 Miles

Vertical-scale exaggeration, 52.1 times

Qyal	-	Younger alluvium
Qoal	-	Older alluvium
Qbg 1/	-	Recent basalt of Goosenest
Qog 1/	-	Latest andesite of Goosenest
QTbw 1/	-	Basalt of Willow Creek Mountain
QTbg 1/	-	Early basalt of Goo
Tvw	-	Volcanic rocks of t
Tu	-	Umpqua formation
Kc	-	Chico formation
pK	-	Basement complex

1/ Volcanic rocks of the High Cascades (QTb) of this report

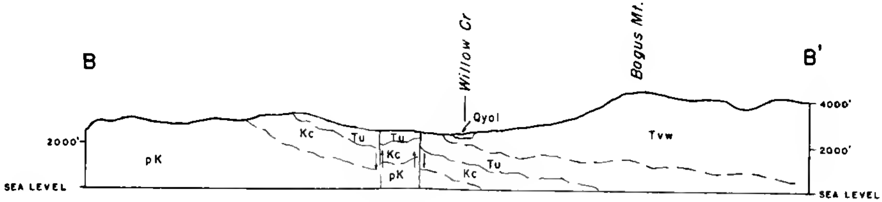


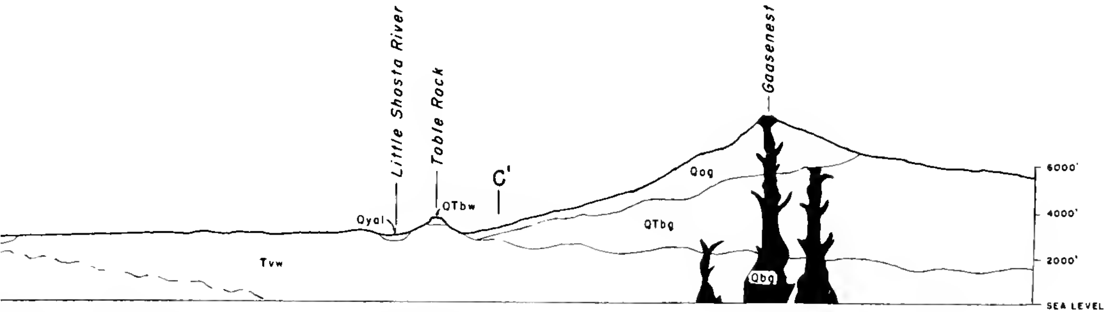
DIAGRAMM

VALLE

Su
of

senest
the Western Cascades
x





In part after Howel Williams, 1949

MATIC SECTIONS B-B' AND C-C' ACROSS SHASTA
EY ILLUSTRATING GEOLOGIC STRUCTURE

0 1 2 3 4 5 Miles

Vertical – scale exaggeration, 2 times

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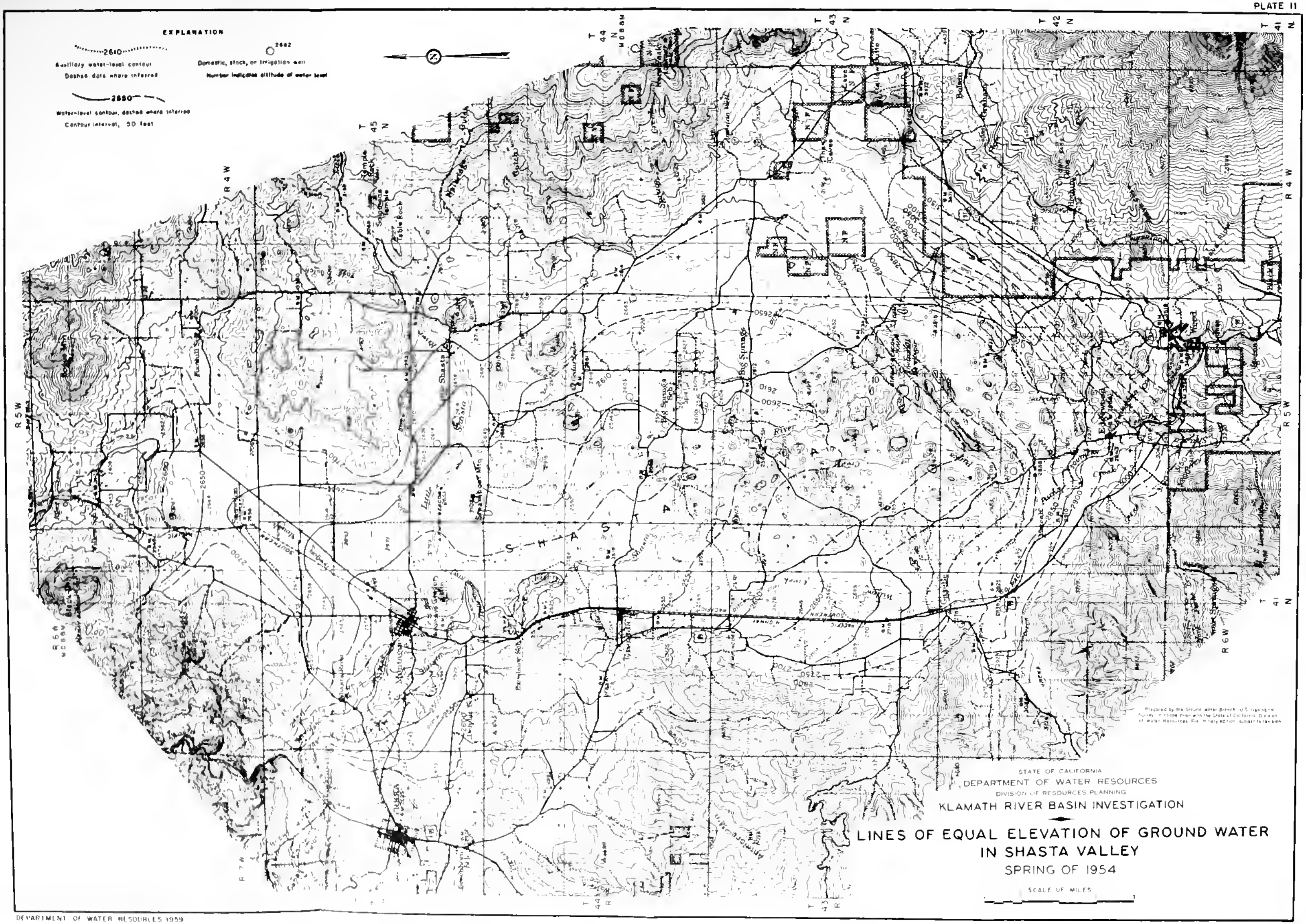
KLAMATH RIVER BASIN INVESTIGATION

GEOLOGIC SECTIONS OF SHASTA VALLEY
1959


EXPLANATION
2610
Auxiliary water-level contour
Dashed dots where inferred
2662
Domestic, stock, or irrigation well
Number indicates altitude of water level
2850
Water-level contour, dashed where inferred
Contour interval, 50 feet
STATE OF CALIFORNIA
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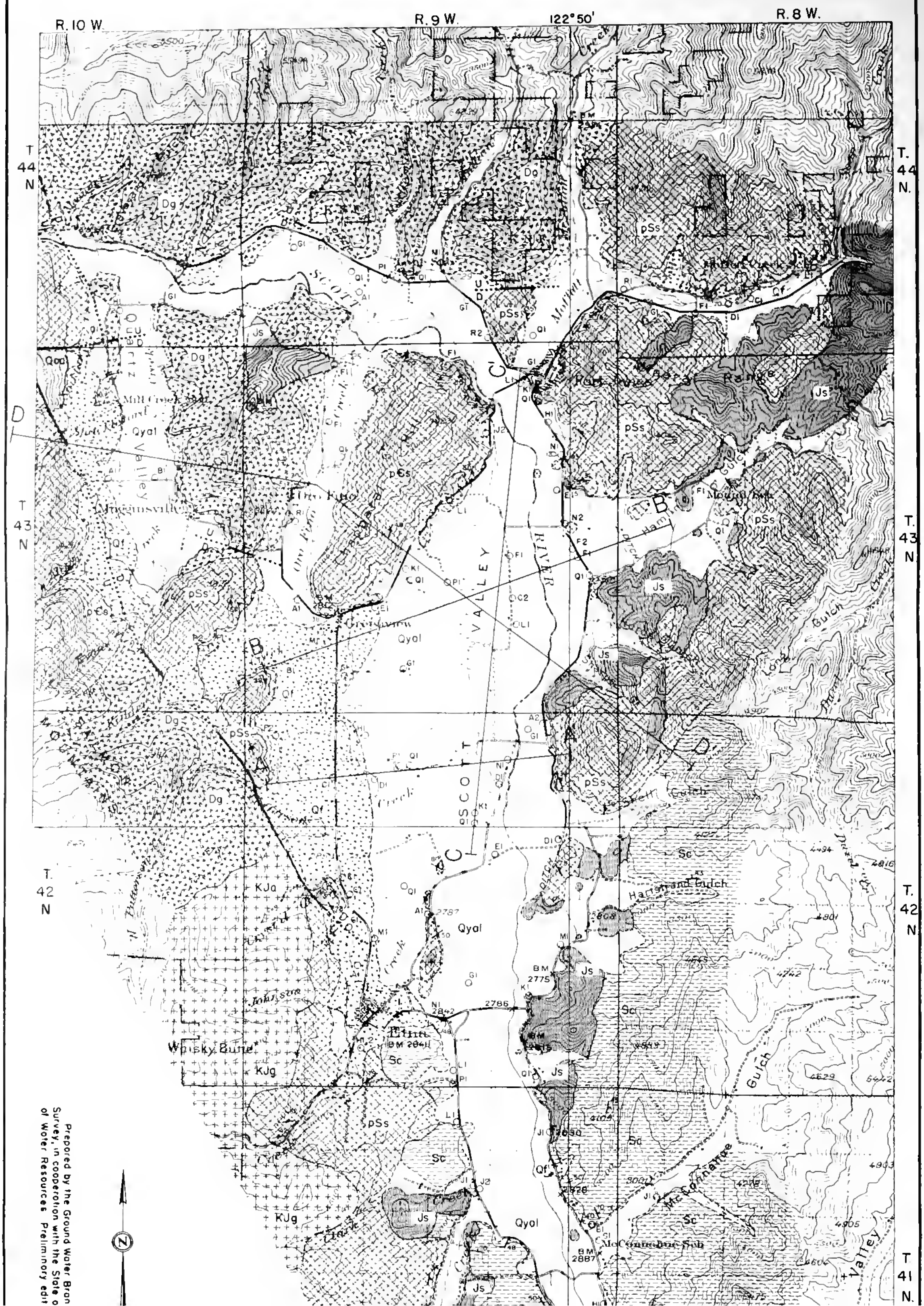
DIVISION OF RESOURCES PLANNING
KLAMATH RIVER BASIN INVESTIGATION
LINES OF EQUAL ELEVATION OF GROUND WATER
IN SHASTA VALLEY
SPRING OF 1954
SCALE OF MILES
SHASTA



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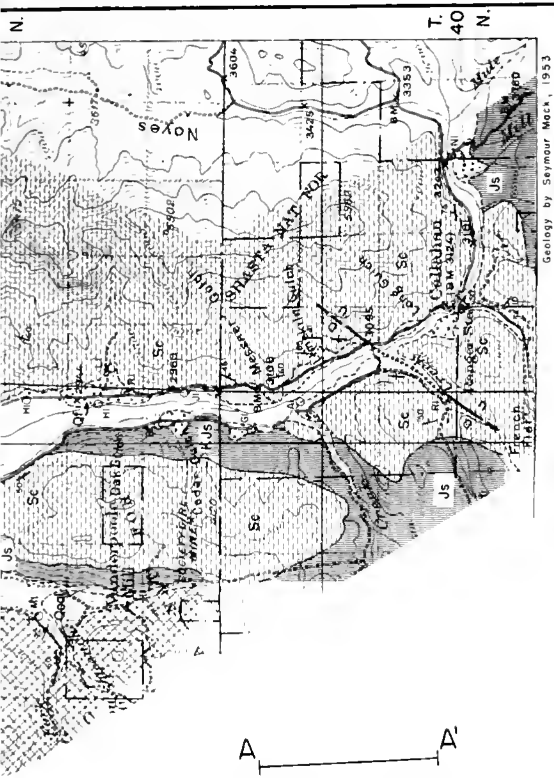
of Water Resources. Preliminary edit



EXPLANATION

QUATERNARY

Recent

Qyal — Alluvium

Stream-channel and flood-plain deposits consisting of unconsolidated sand, gravel, and clay deposited by Scott River and its tributaries. Yields abundant water to wells

Qf — Alluvial-fan deposits

Coarse bouldery deposits in a matrix of sandy clay in upland areas, grading valleyward to fine sand and clay. Yields water sufficient for domestic and stock purposes

Pleistocene

Qoal — Older alluvium

Alluvial-fan and terrace deposits along valley margins. Generally consist of poorly sorted bouldery deposits in a matrix of sand and silty clay. Not important as an aquifer because of limited extent and position generally above the water table

JURASSIC OR CRETACEOUS

Upper Jurassic or Lower Cretaceous

KJg — Granodiorite

Light-gray medium- to coarse-grained massive rock. Largely granodiorite but composition ranges from granite to quartz diorite. Essentially not water bearing

JURASSIC

Upper Jurassic

Js — Serpentine

Intrusive masses of peridotite almost completely altered to minerals of the serpentine group. Essentially not water bearing

DEVONIAN(?)

Dg — Greenstone

Andesitic volcanic rocks altered to greenstone and greenstone schist. Sedimentary interbeds of chert, argillite, and limestone. Essentially not water bearing

SILURIAN

Sc — Chanchelulla formation (?) of Hinds (1931)

Chert, quartzite, slate, and limestone. Essentially not water bearing

PRE-SILURIAN

pSs — Abrams mica schist and Salmon hornblende schist

Abrams mica schist is of sedimentary origin and is primarily quartz mica schist with minor beds of graphite and actinolite schist and blue marble. The Salmon hornblende schist overlies the Abrams schist unconformably, is of volcanic origin, and is composed mainly of hornblende schist and gneiss. Both are essentially not water bearing

Geologic contact
(Dashed where uncertain or vague)

Alluvial contact

Fault
(Dashed where uncertain)
(Dotted where concealed)

U: upthrown side
D: downthrown side

A — A'
Location of geologic cross-section

30
Strike and dip of sedimentary rocks

80
Strike and dip of foliated rocks

P1
Well location and number

Branch, U.S. Geological
tate of California, Division
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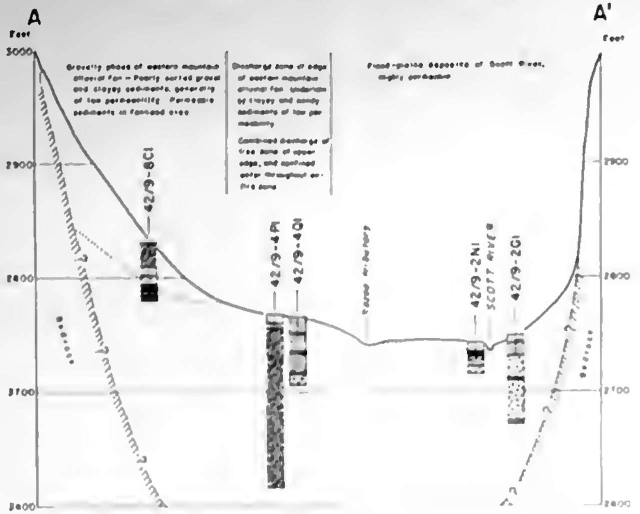
KLAMATH RIVER BASIN INVESTIGATION

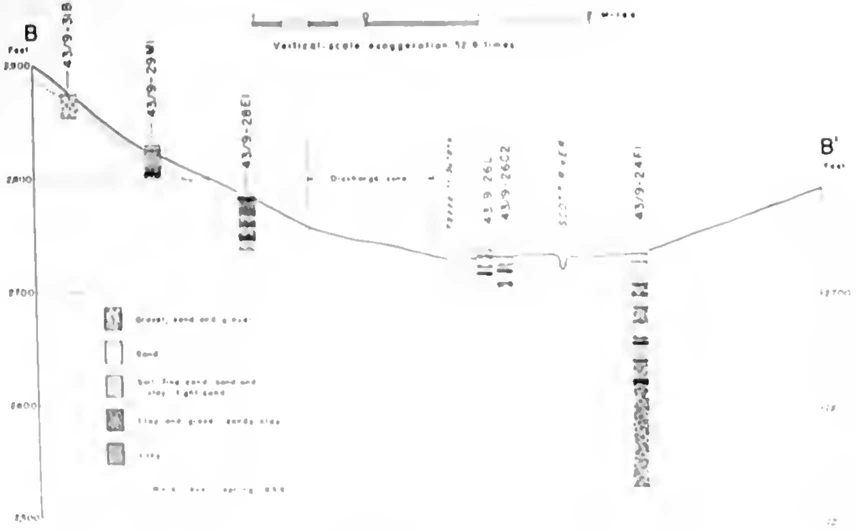
GEOLOGIC MAP OF SCOTT VALLEY
1959

SCALE OF MILES
0 1 2 3

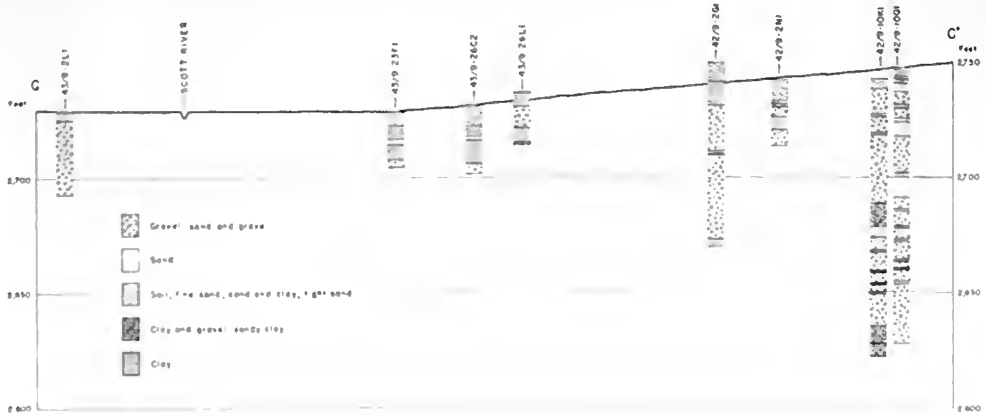


GEOLOGIC SECTION A-A'

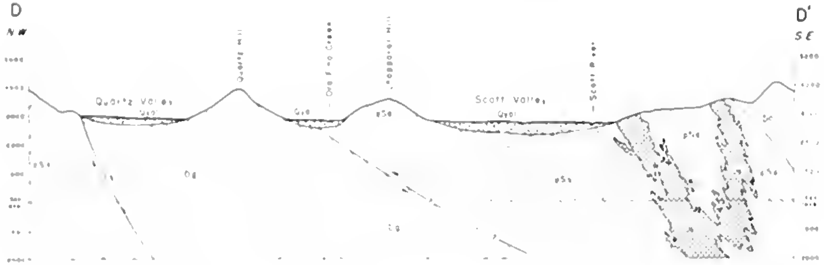
Vertical-scale exaggeration 52.8 times



GEOLOGIC SECTION B-B'



LONGITUDINAL SECTION ALONG TROUGH OF SCOTT VALLEY
FROM NEAR ETNA TO FORT JONES



DIAGRAMMATIC SECTION ACROSS SCOTT VALLEY
ILLUSTRATING STRUCTURE OF THE BEDROCK UNITS

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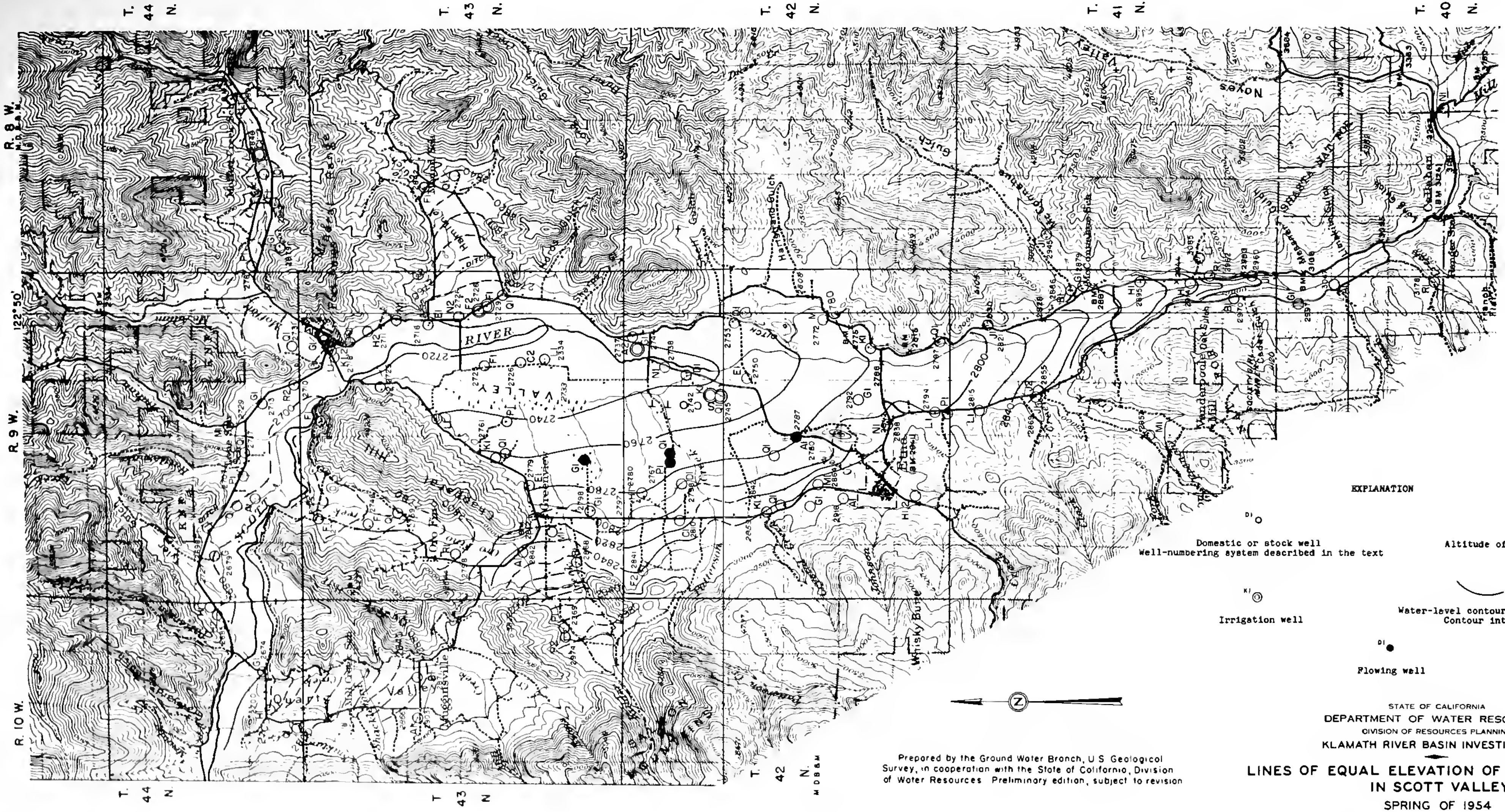
KLAMATH RIVER BASIN INVESTIGATION

GEOLOGIC SECTIONS OF SCOTT VALLEY
1959



EXPLANATION

Domestic or stock well
Well-numbering system described in the text

Altitude of the water level

Irrigation well

Water-level contour, dashed where inferred
Contour interval, 20 feet

Flowing well

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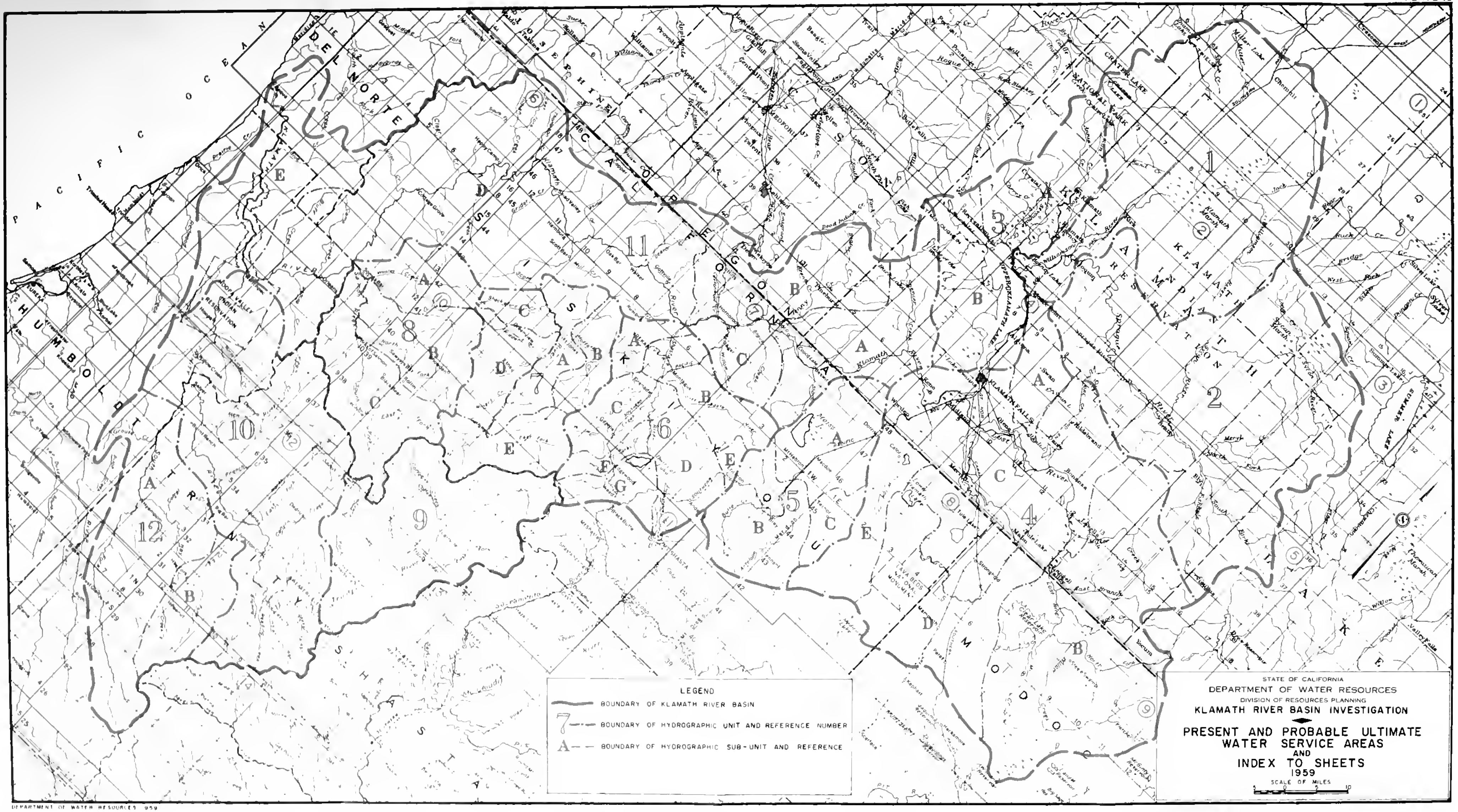
KLAMATH RIVER BASIN INVESTIGATION

LINES OF EQUAL ELEVATION OF GROUND WATER IN SCOTT VALLEY

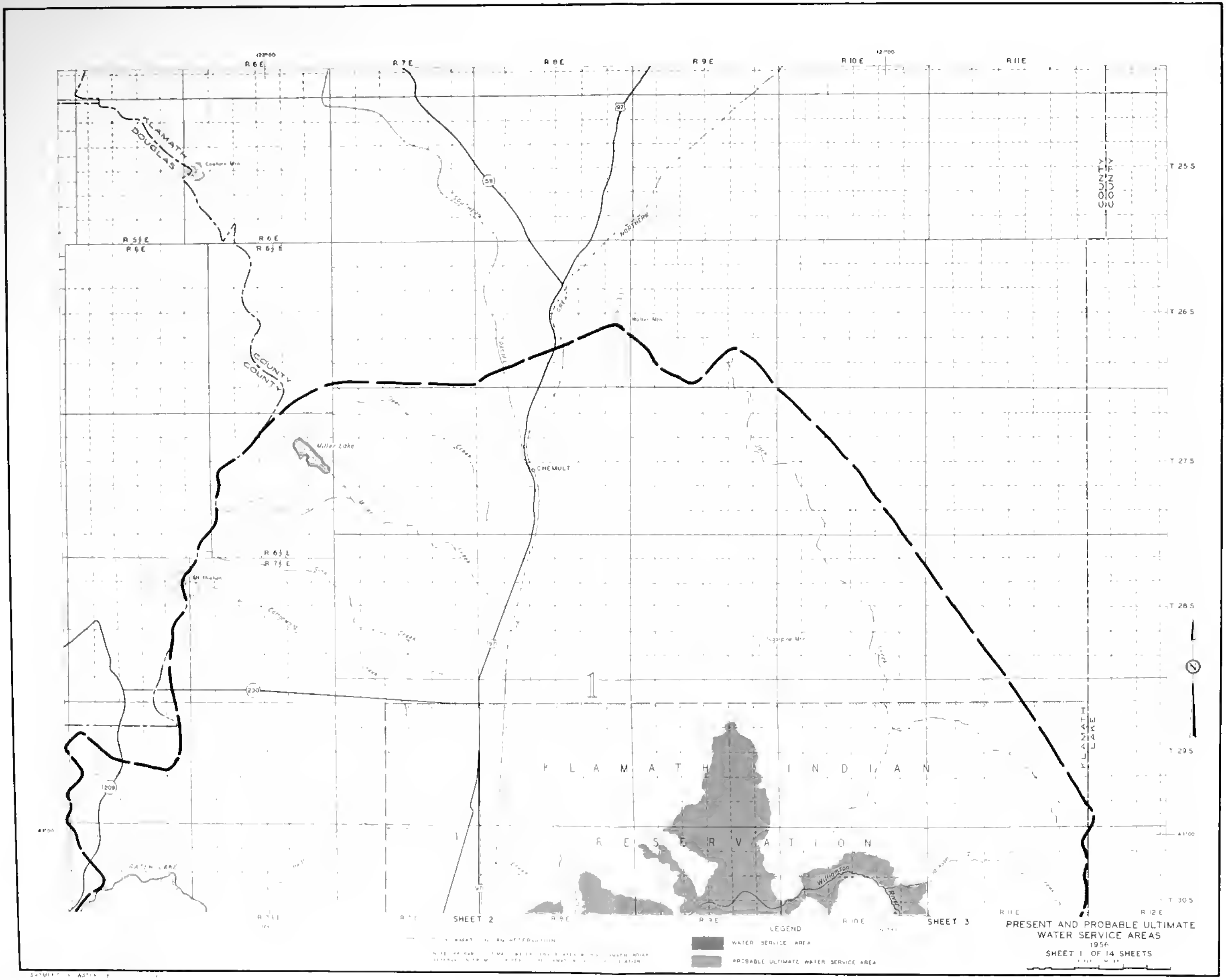
SPRING OF 1954

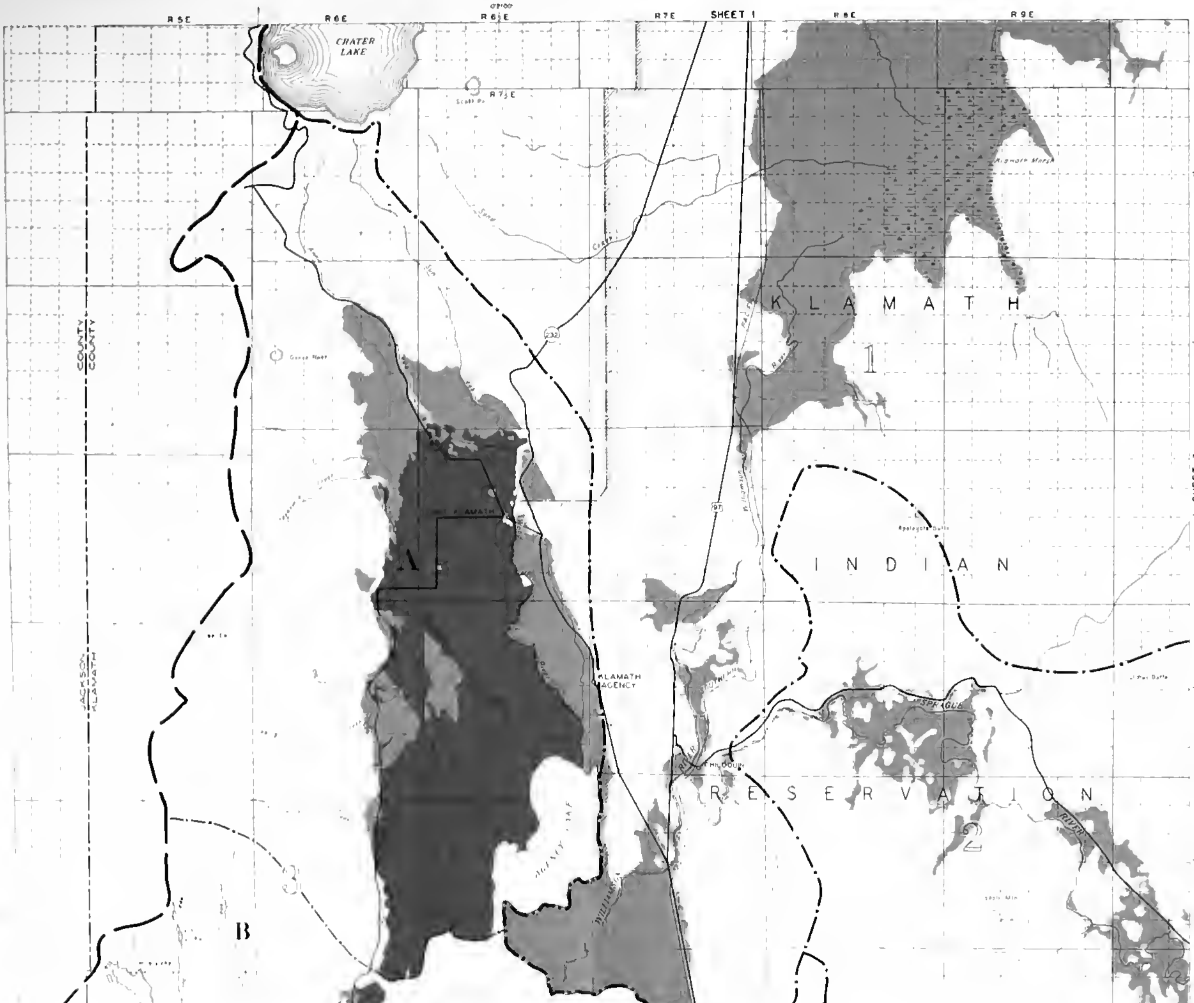
SCALE OF MILES

PLATE 15



DEPARTMENT OF WATER RESOURCES 1959


R 6 E
R 7 E
R 8 E
R 9 E
R 10 E
R 11 E
KLAMATH
DOUGLAS
COUNTY
COUNTY
T 25 S
T 26 S
T 27 S
T 28 S
T 29 S
T 30 S
R 5½ E
R 6 E
R 6½ E
Miller Lake
CHEMULT
Walker Mtn
NORTHERN
97
58
230
209
KLAMATH INDIAN RESERVATION
Williamson River
KLAMATH LAKE
SHEET 2
SHEET 3
R 11 E
R 12 E
LEGEND
WATER SERVICE AREA
PROBABLE ULTIMATE WATER SERVICE AREA
PRESENT AND PROBABLE ULTIMATE
WATER SERVICE AREAS
1956
SHEET 1 OF 14 SHEETS

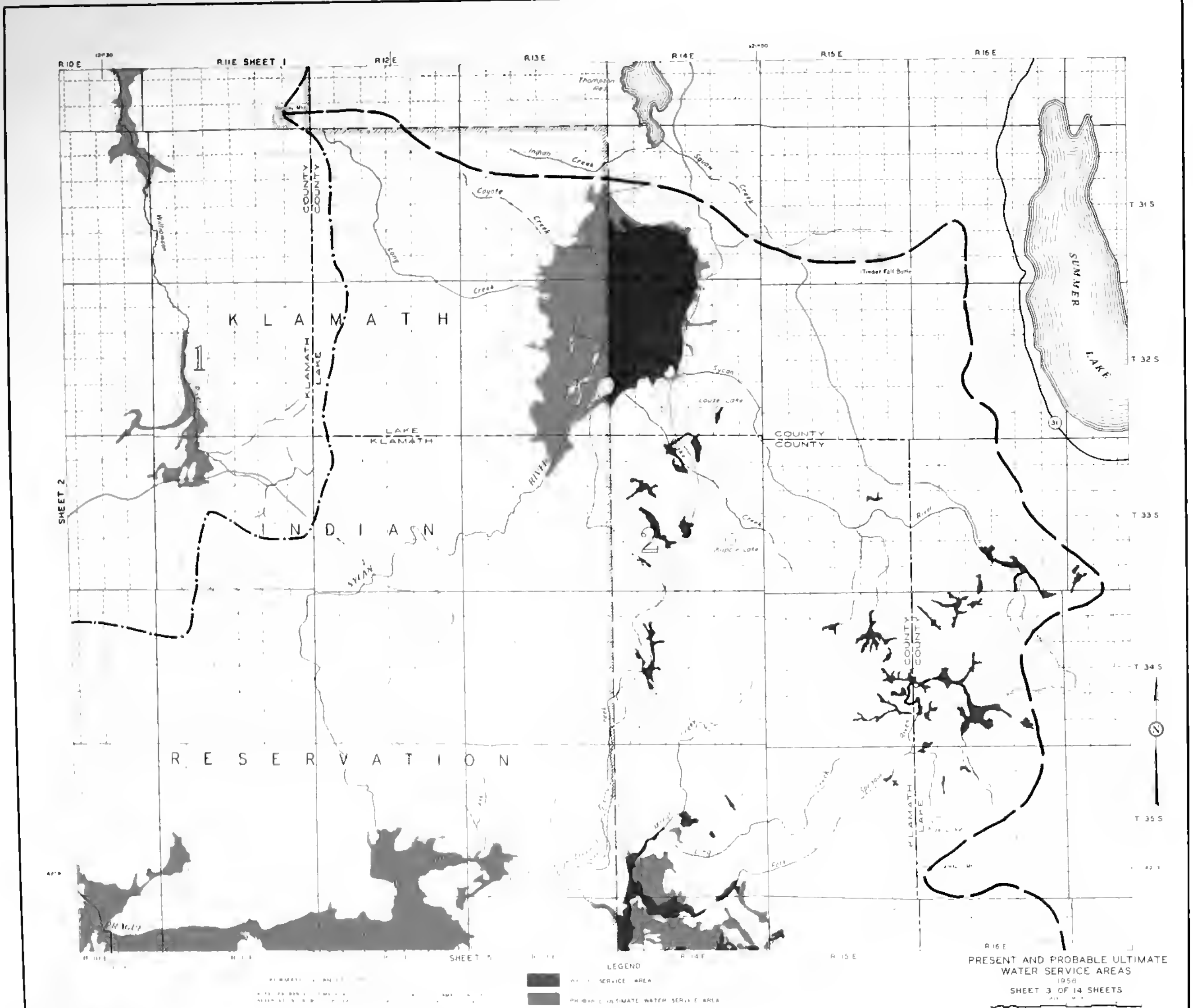


LEGEND

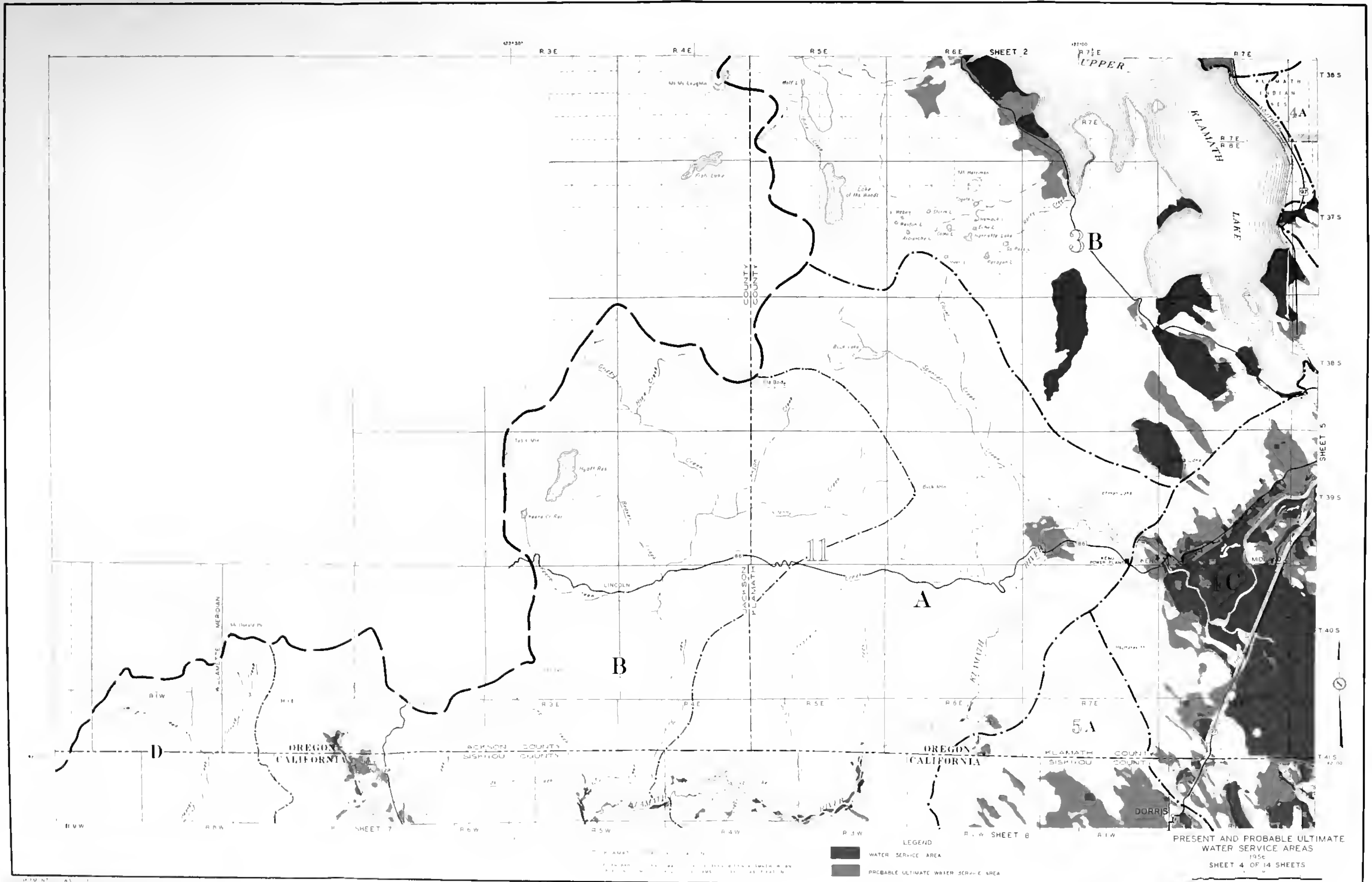
WATER SERVICE AREA

PROBABLE ULTIMATE WATER SERVICE AREA

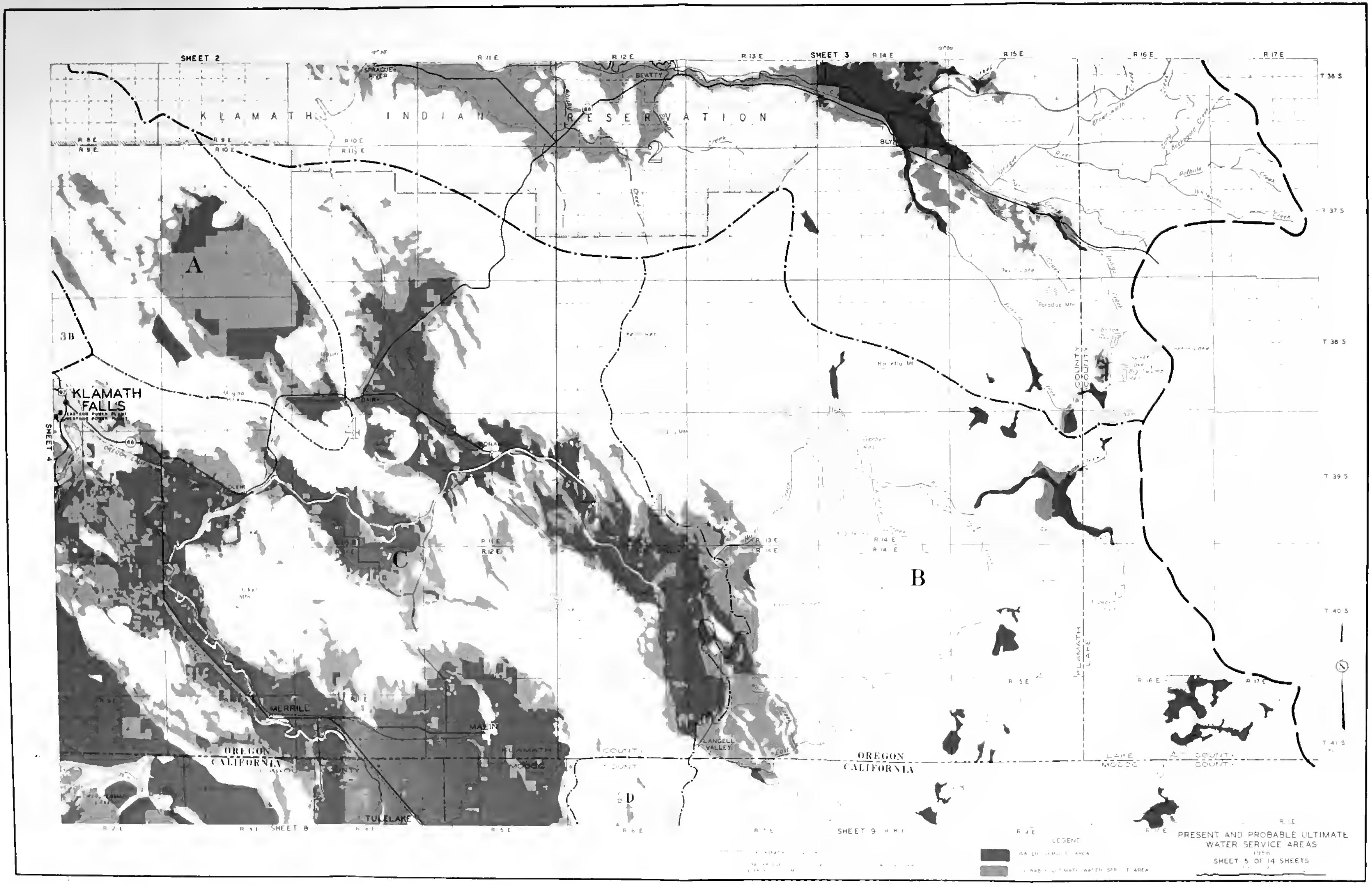
PRESENT AND PROBABLE ULTIMATE
WATER SERVICE AREAS
1956
SHEET 2 OF 14 SHEETS

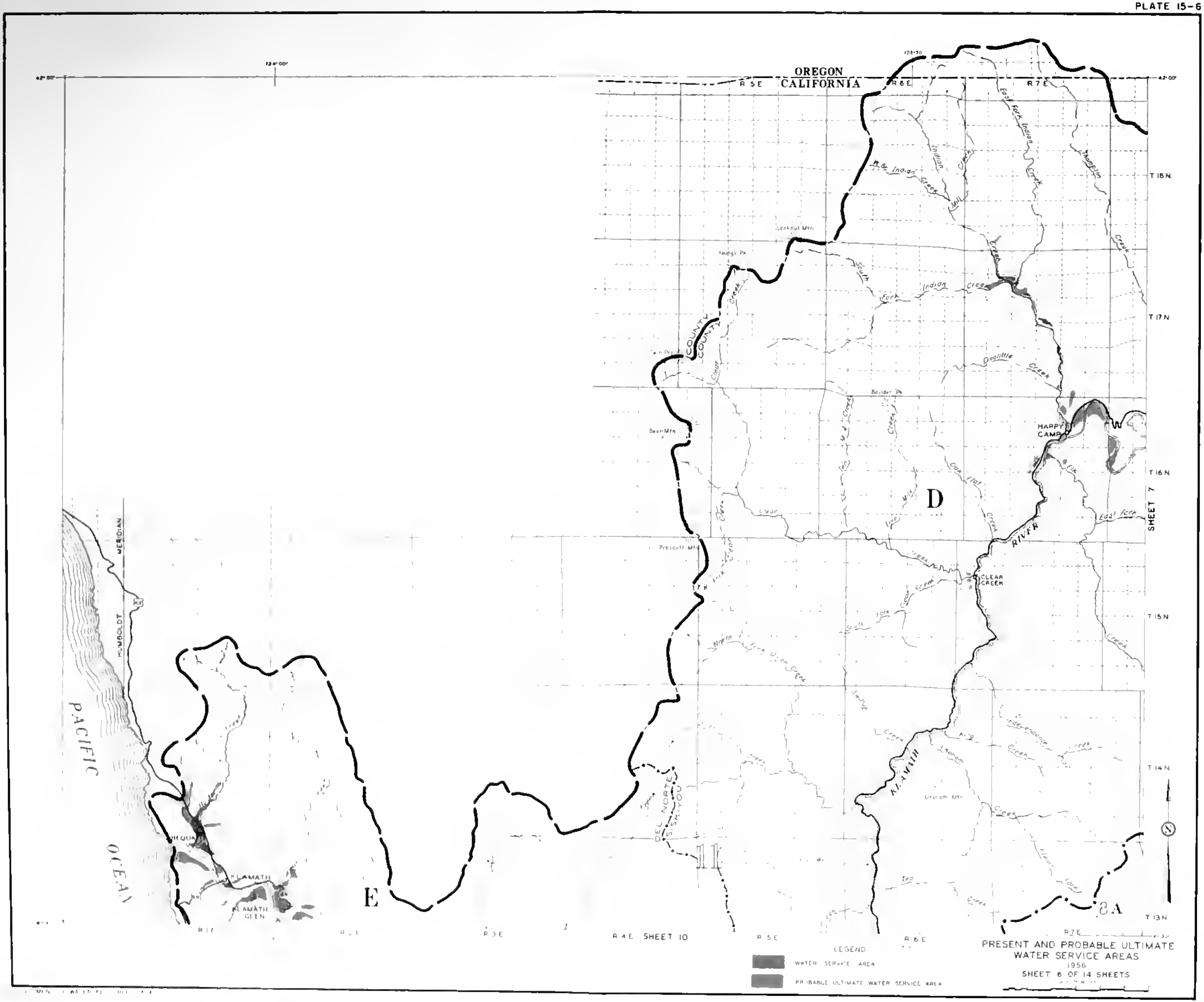


PRESENT AND PROBABLE ULTIMATE
WATER SERVICE AREAS
1956
SHEET 3 OF 14 SHEETS

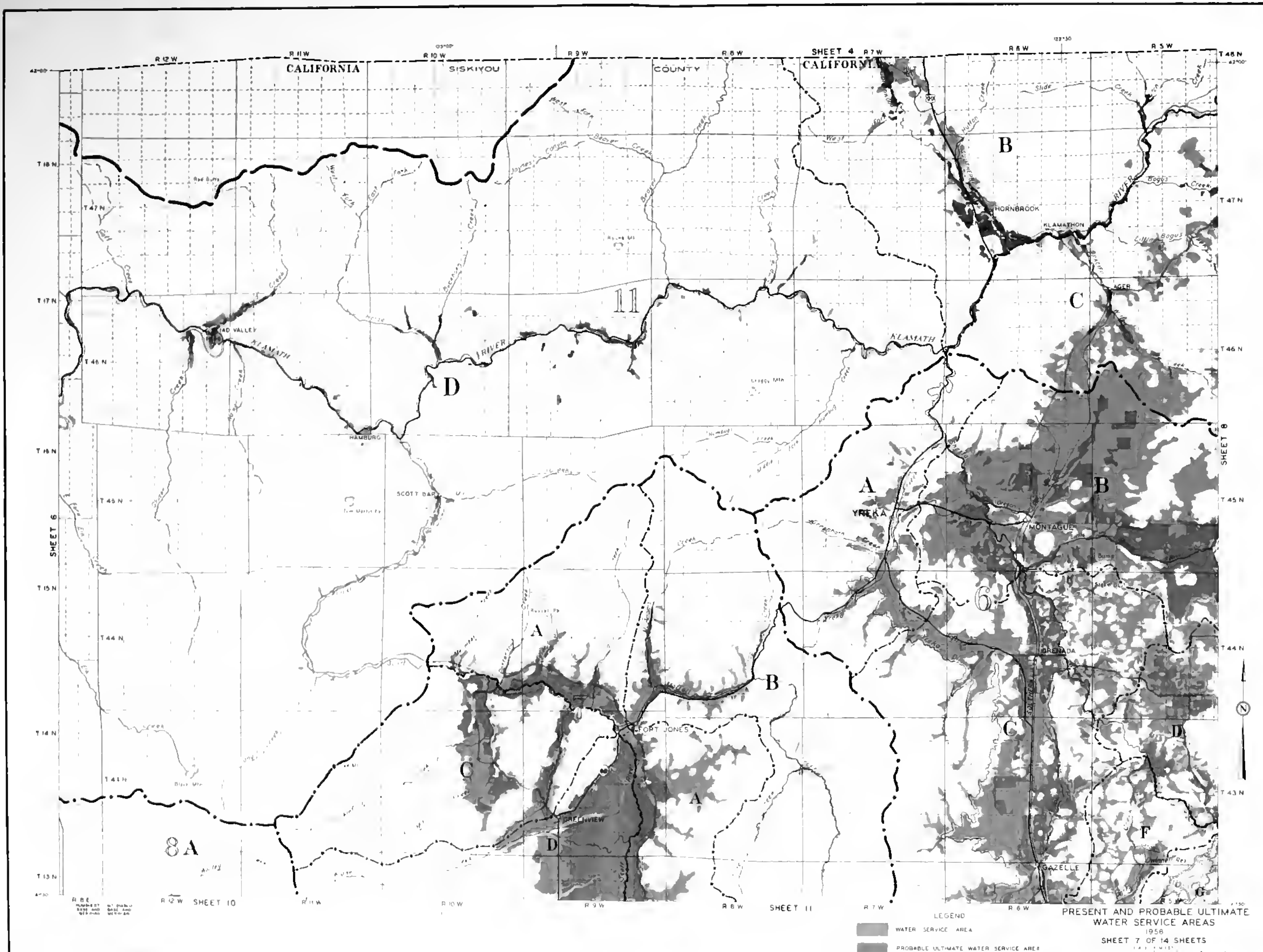


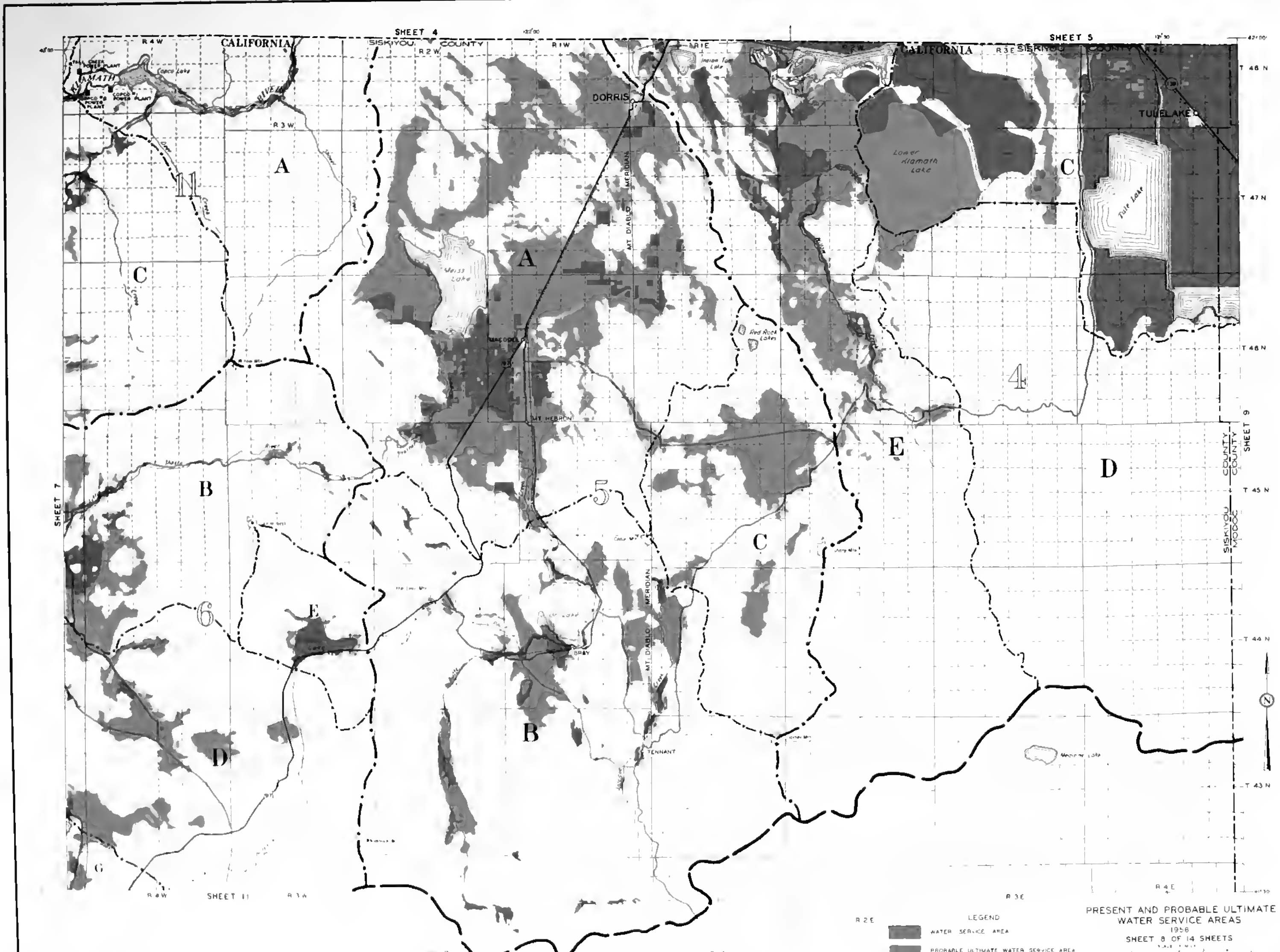
PRESENT AND PROBABLE ULTIMATE WATER SERVICE AREAS
1956
SHEET 4 OF 14 SHEETS


SHEET 2
SHEET 3
KLAMATH INDIAN RESERVATION
BEATTY
BLY
SPRAGUE RIVER
A
B
C
D
2
3B
KLAMATH FALLS
SHEET 4
DAIRY
MERRILL
MALIN
TULELAKE
LANGELL VALLEY
OREGON
CALIFORNIA
KLAMATH
MODOC
LAKE
COUNTY
SHEET 8
SHEET 9
R 11 E
R 12 E
R 13 E
R 14 E
R 15 E
R 16 E
R 17 E
T 38 S
T 37 S
T 39 S
T 40 S
T 41 S
LEGEND
PRESENT AND PROBABLE ULTIMATE
WATER SERVICE AREAS
1956
SHEET 5 OF 14 SHEETS

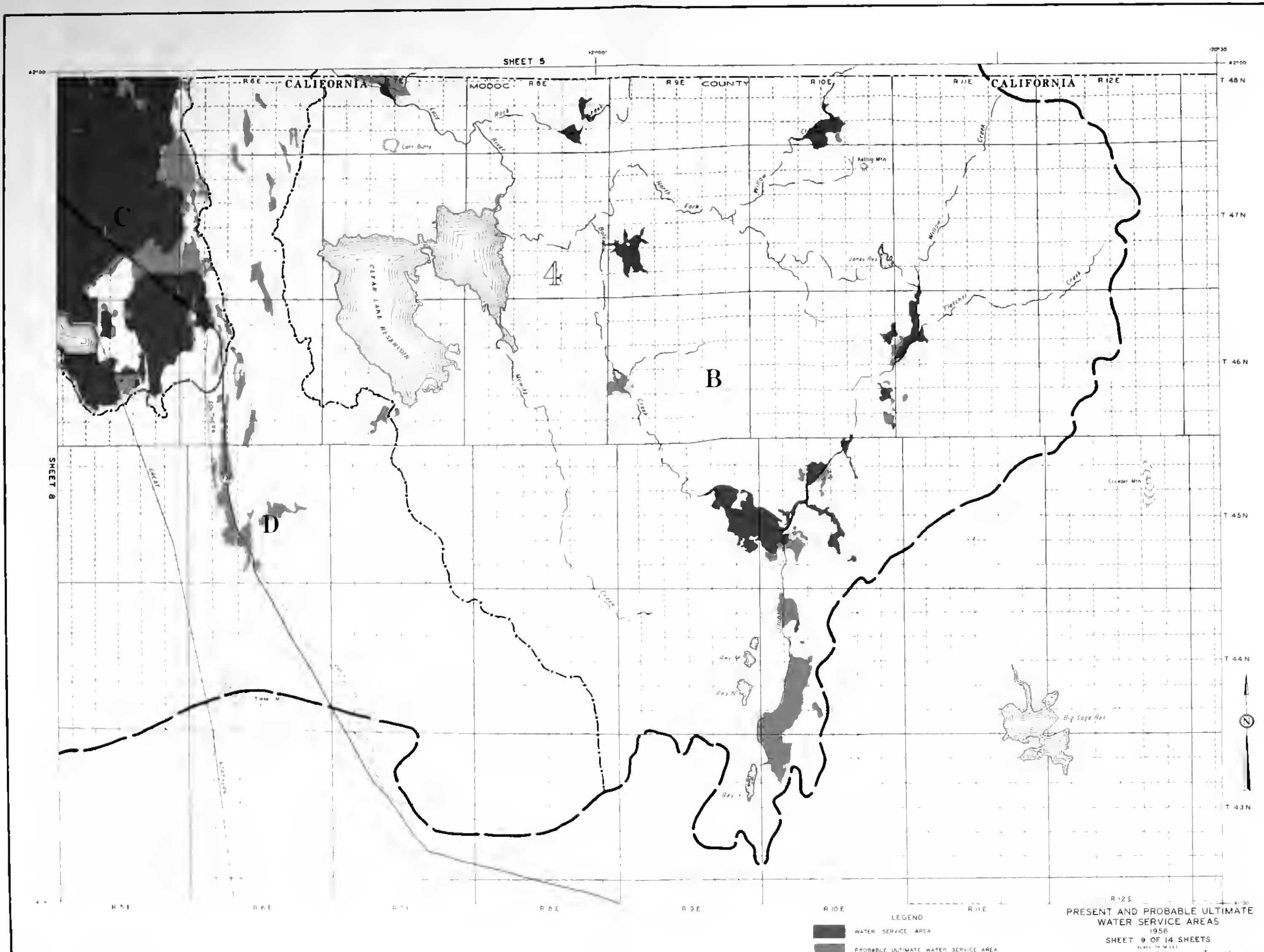


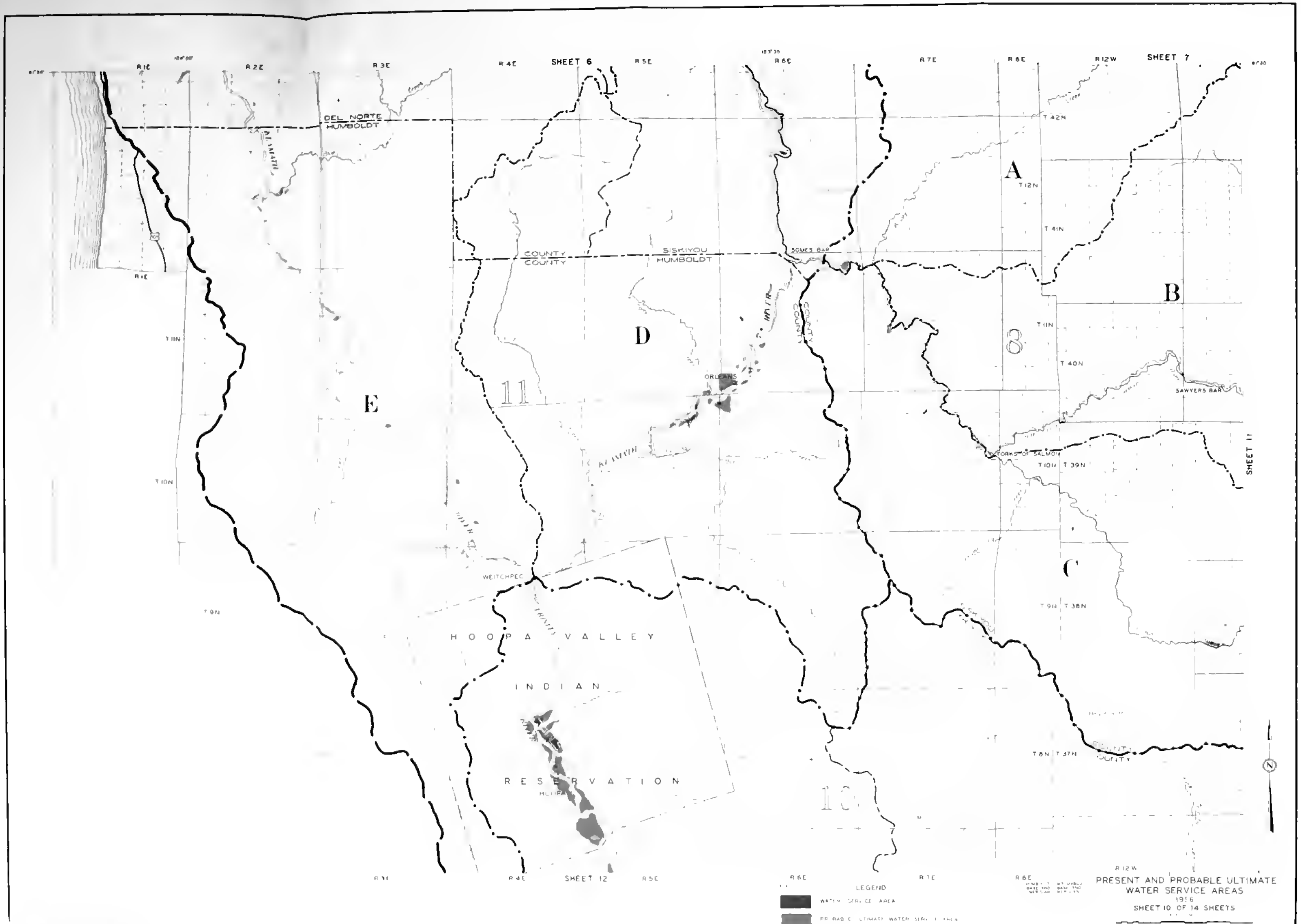
PRESENT AND PROBABLE ULTIMATE WATER SERVICE AREAS
1956
SHEET 6 OF 14 SHEETS


CALIFORNIA
SISKIYOU
COUNTY
SHEET 4
CALIFORNIA
R 12 W
R 11 W
R 10 W
R 9 W
R 8 W
R 7 W
R 6 W
R 5 W
T 48 N
T 47 N
T 46 N
T 45 N
T 44 N
T 43 N
T 18 N
T 17 N
T 16 N
T 15 N
T 14 N
T 13 N
SHEET 6
SHEET 8
SHEET 10
SHEET 11
HORNBROOK
KLAMATHON
AGER
HAPPY CAMP
HAMBURG
SCOTT BAR
YREKA
MONTAGUE
GRENADA
GAZELLE
FORT JONES
GREENVIEW
KLAMATH
RIVER
11
2
6
8A
A
B
C
D
F
G
LEGEND
WATER SERVICE AREA
PROBABLE ULTIMATE WATER SERVICE AREA
PRESENT AND PROBABLE ULTIMATE
WATER SERVICE AREAS
1958
SHEET 7 OF 14 SHEETS



PRESENT AND PROBABLE ULTIMATE WATER SERVICE AREAS
1958
SHEET 8 OF 14 SHEETS

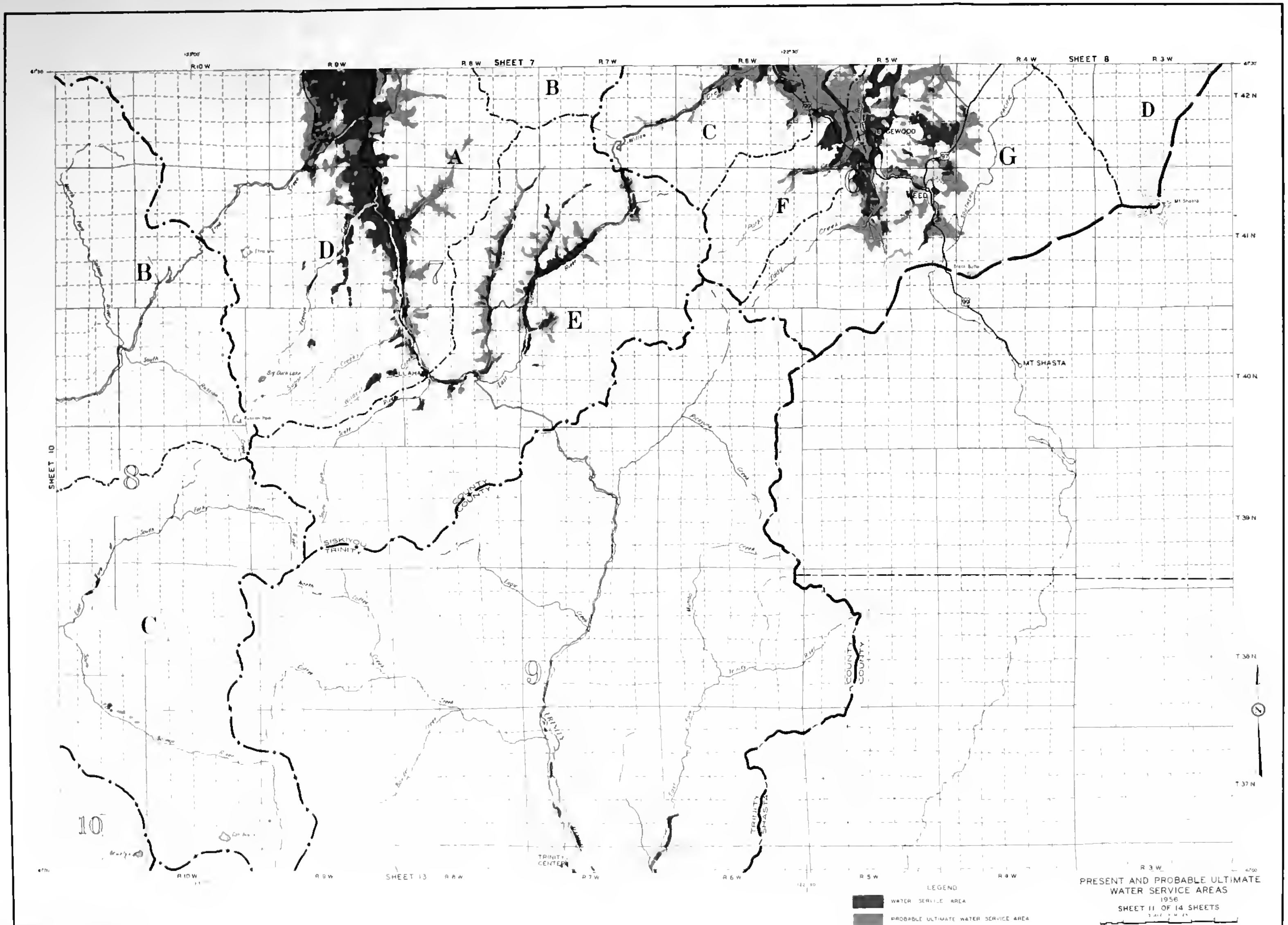

SHEET 5
CALIFORNIA
MODOC
COUNTY
CALIFORNIA
R 6 E
R 8 E
R 9 E
R 10 E
R 11 E
R 12 E
T 48 N
T 47 N
T 46 N
T 45 N
T 44 N
T 43 N
SHEET 8
C
4
B
D
CLEAR LAKE RESERVOIR
Big Sage Res
Jones Res
Kellog Mtn
Crowder Mtn
Willow
Creek
North Fork
Fletcher Creek
LEGEND
WATER SERVICE AREA
PROBABLE ULTIMATE WATER SERVICE AREA
PRESENT AND PROBABLE ULTIMATE
WATER SERVICE AREAS
1956
SHEET 9 OF 14 SHEETS



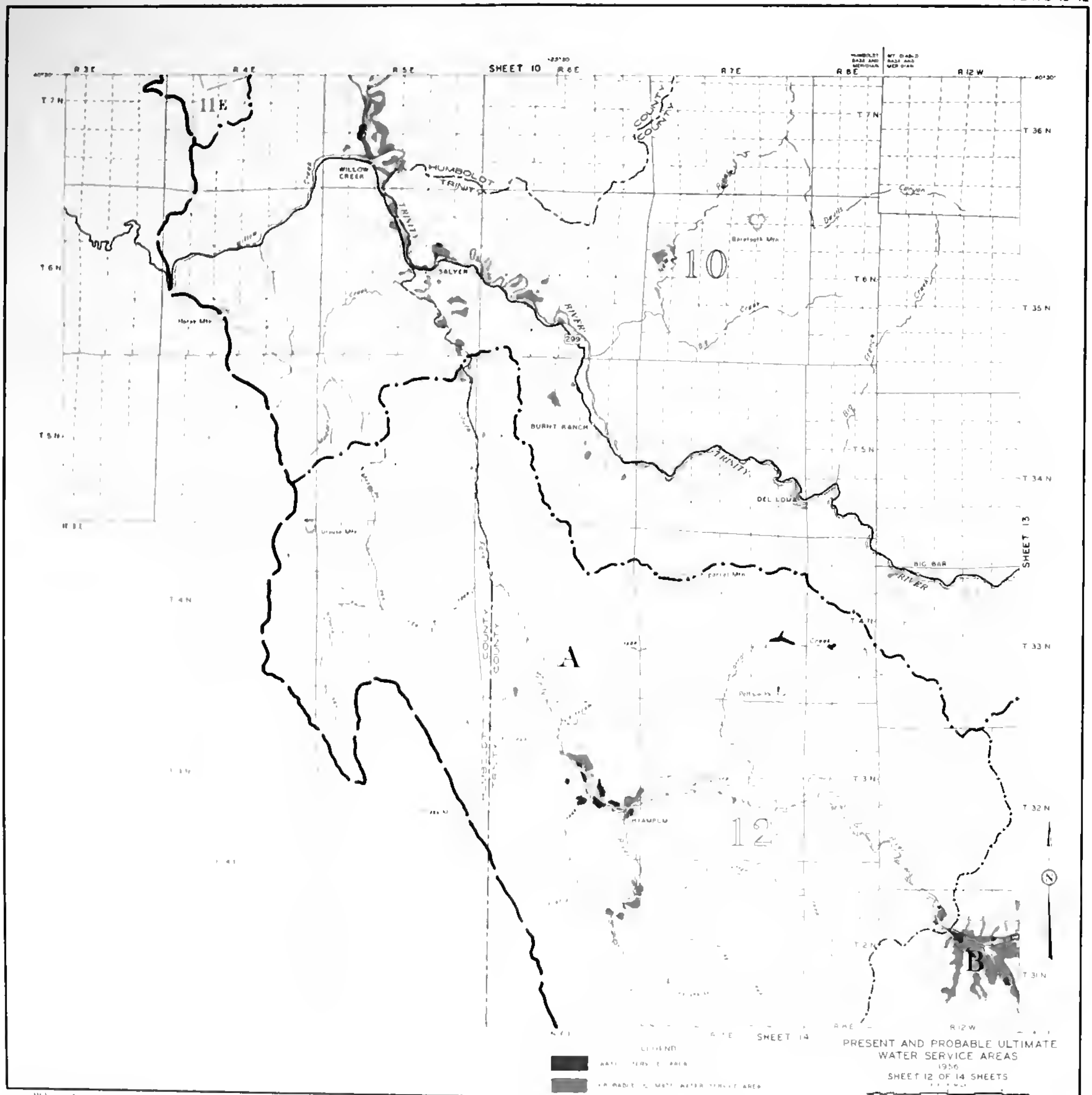
PRESENT AND PROBABLE ULTIMATE WATER SERVICE AREAS

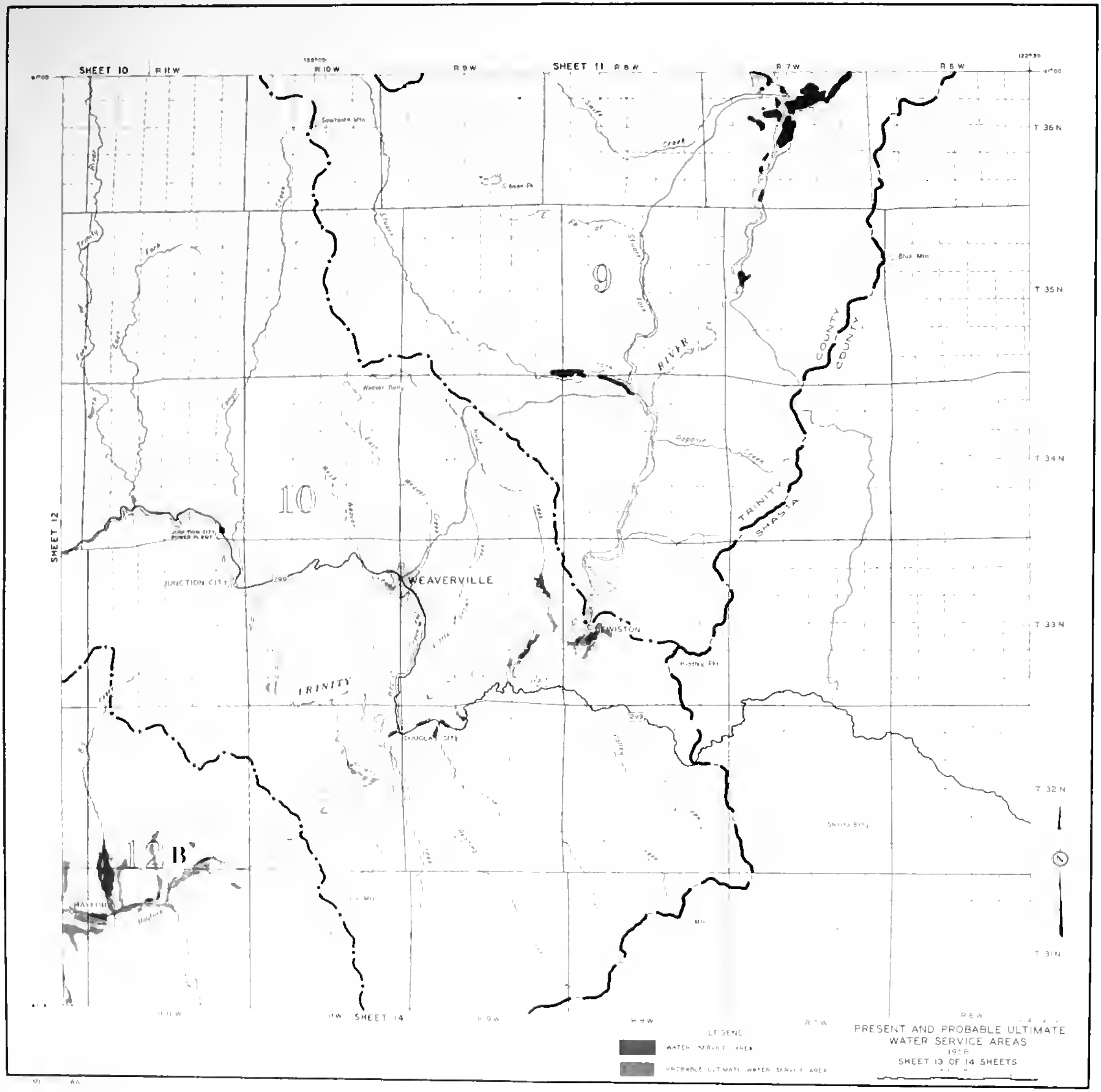
1956

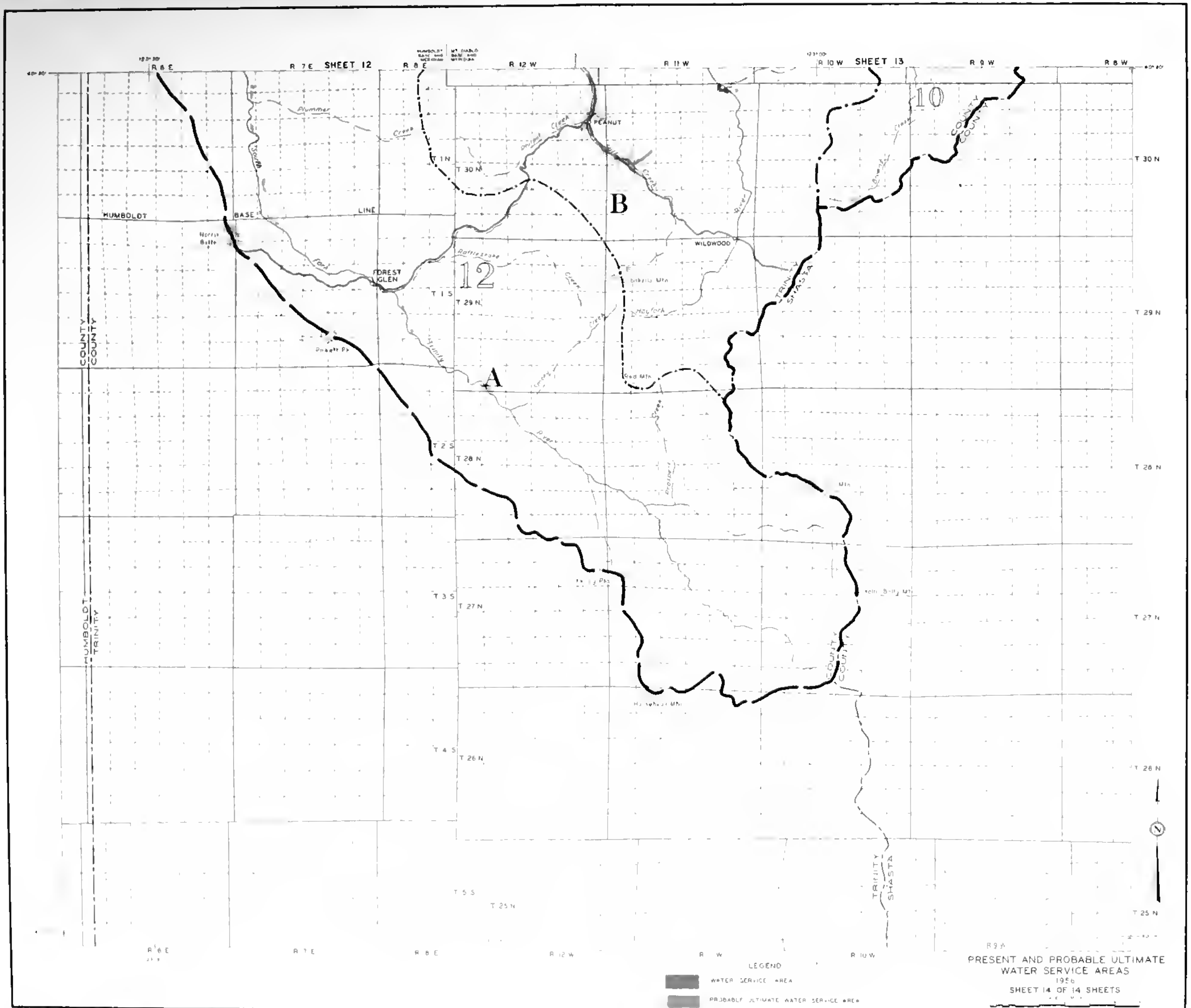
SHEET 10 OF 14 SHEETS



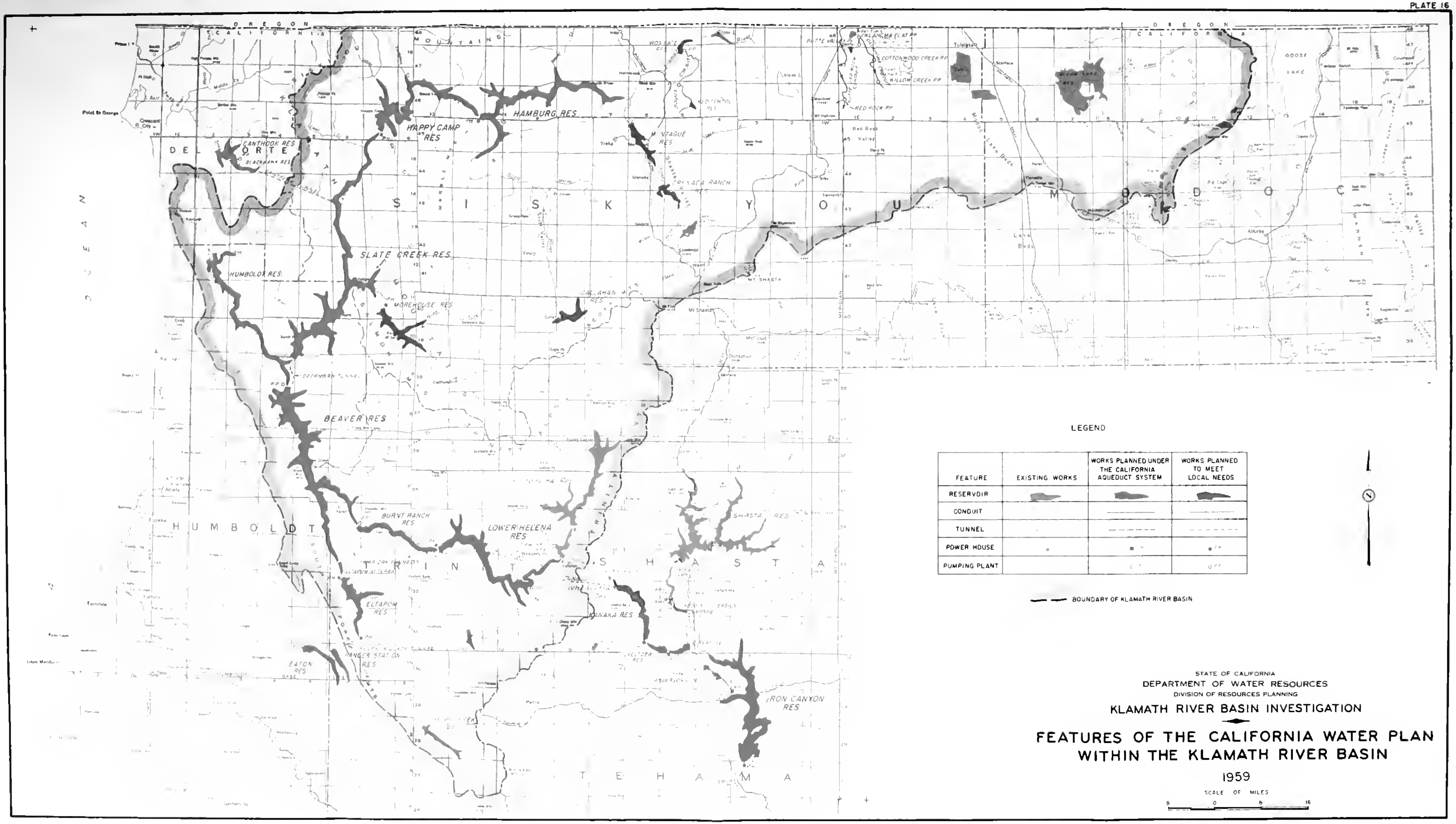
PRESENT AND PROBABLE ULTIMATE WATER SERVICE AREAS
1958
SHEET 11 OF 14 SHEETS

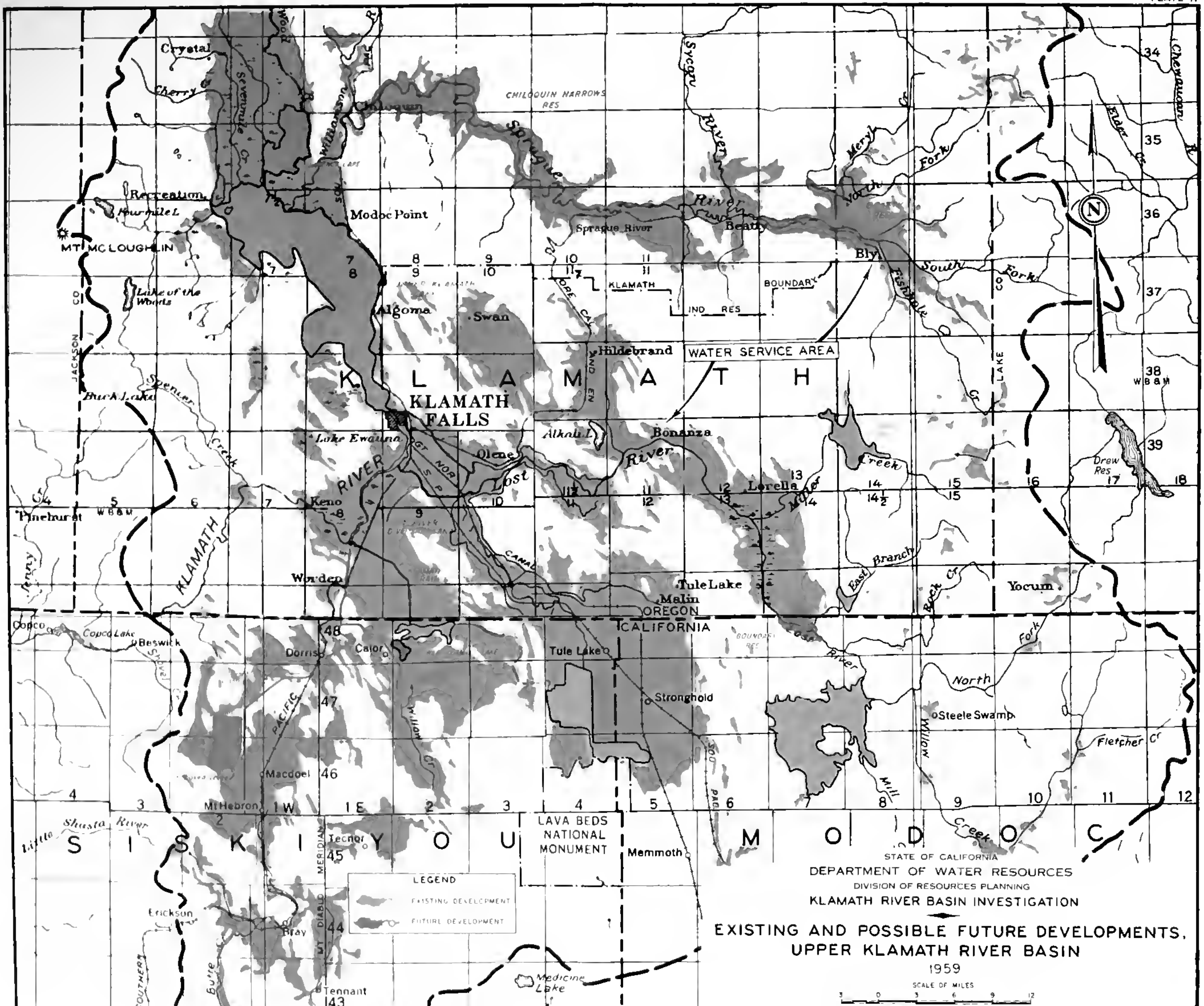

SHEET 10
R 3 E
R 4 E
R 5 E
R 6 E
R 7 E
R 8 E
R 12 W
T 7 N
T 6 N
T 5 N
T 4 N
T 36 N
T 35 N
T 34 N
T 33 N
T 32 N
T 31 N
T 2 N
T 3 N
11E
10
A
12
B
WILLOW CREEK
HUMBOLDT
TRINITY
COUNTY
SALYER
TRINITY RIVER
299
BURNT RANCH
DEL LOMA
BIG BAR
RIVER
HYAMPOM
SHEET 13
SHEET 14
LEGEND
PRESENT AND PROBABLE ULTIMATE
WATER SERVICE AREAS
1956
SHEET 12 OF 14 SHEETS


SHEET 10
SHEET 11
SHEET 12
SHEET 14
R 11 W
R 10 W
R 9 W
R 8 W
R 7 W
R 6 W
T 36 N
T 35 N
T 34 N
T 33 N
T 32 N
T 31 N
WEAVERVILLE
JUNCTION CITY
LEWISTON
DOUGLAS CITY
TRINITY
SHASTA
COUNTY
RIVER
9
10
12B
299
Blue Mtn
Weaver Bally
Shasta Bally
LEGEND
WATER SERVICE AREA
PROBABLE ULTIMATE WATER SERVICE AREA
PRESENT AND PROBABLE ULTIMATE
WATER SERVICE AREAS
1956
SHEET 13 OF 14 SHEETS



PRESENT AND PROBABLE ULTIMATE
WATER SERVICE AREAS
1956
SHEET 14 OF 14 SHEETS


OREGON
CALIFORNIA
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
TEHAMA
OCEAN
HAPPY CAMP RES
HAMBURG RES
CANTHOOK RES
SLATE CREEK RES
HUMBOLDT RES
MOREHOUSE RES
BEAVER RES
BURNT RANCH RES
LOWER HELENA RES
ELTAPOM RES
KANAKA RES
SHASTA RES
IRON CANYON RES
EATON RES
MONTAGUE RES
COTTONWOOD CREEK PP
WILLOW CREEK PP
RED ROCK PP
CALLAHAN RES
MT SHASTA
LEGEND
FEATURE
EXISTING WORKS
WORKS PLANNED UNDER THE CALIFORNIA AQUEDUCT SYSTEM
WORKS PLANNED TO MEET LOCAL NEEDS
RESERVOIR
CONDUIT
TUNNEL
POWER HOUSE
PUMPING PLANT
BOUNDARY OF KLAMATH RIVER BASIN
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
KLAMATH RIVER BASIN INVESTIGATION
FEATURES OF THE CALIFORNIA WATER PLAN WITHIN THE KLAMATH RIVER BASIN
1959
SCALE OF MILES

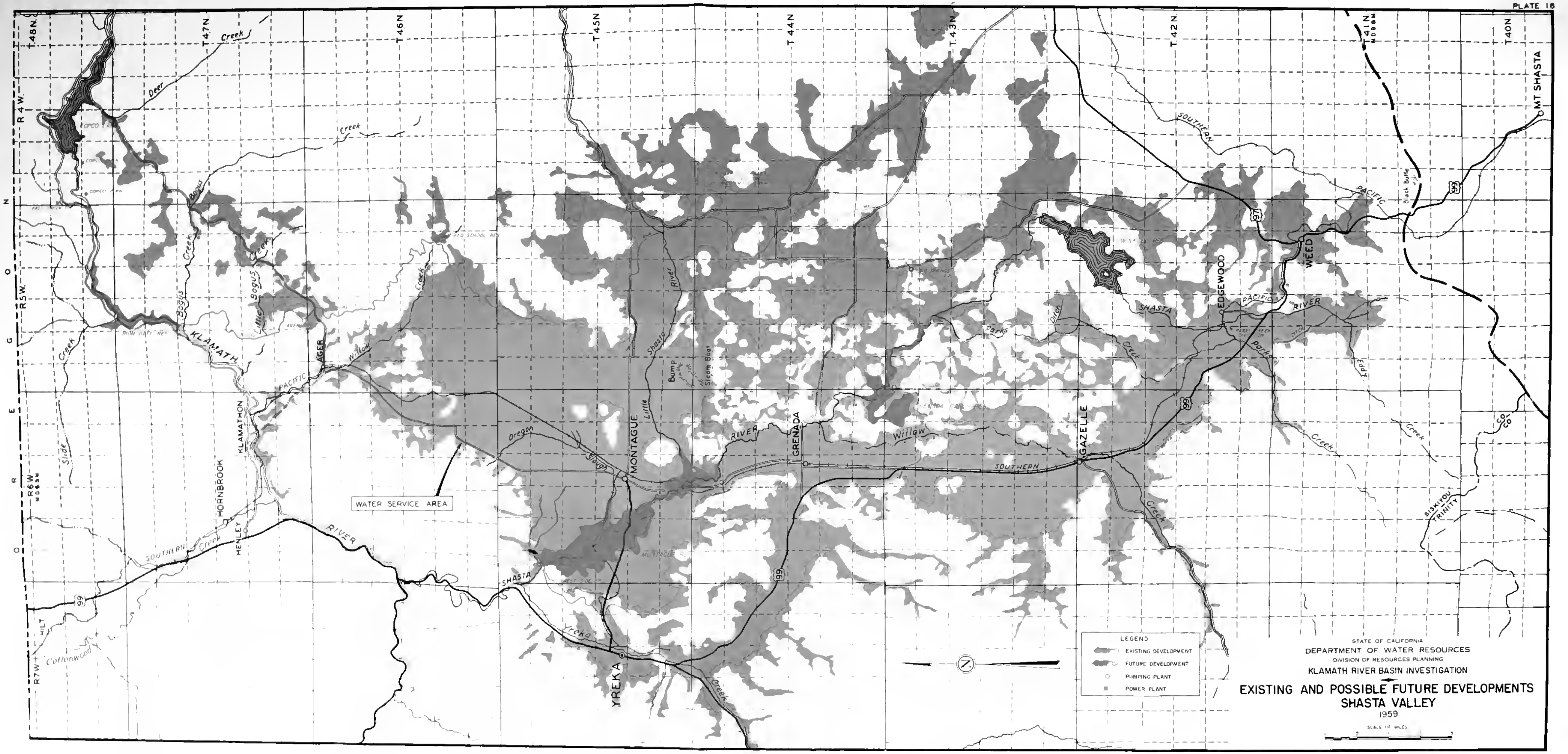


STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
KLAMATH RIVER BASIN INVESTIGATION

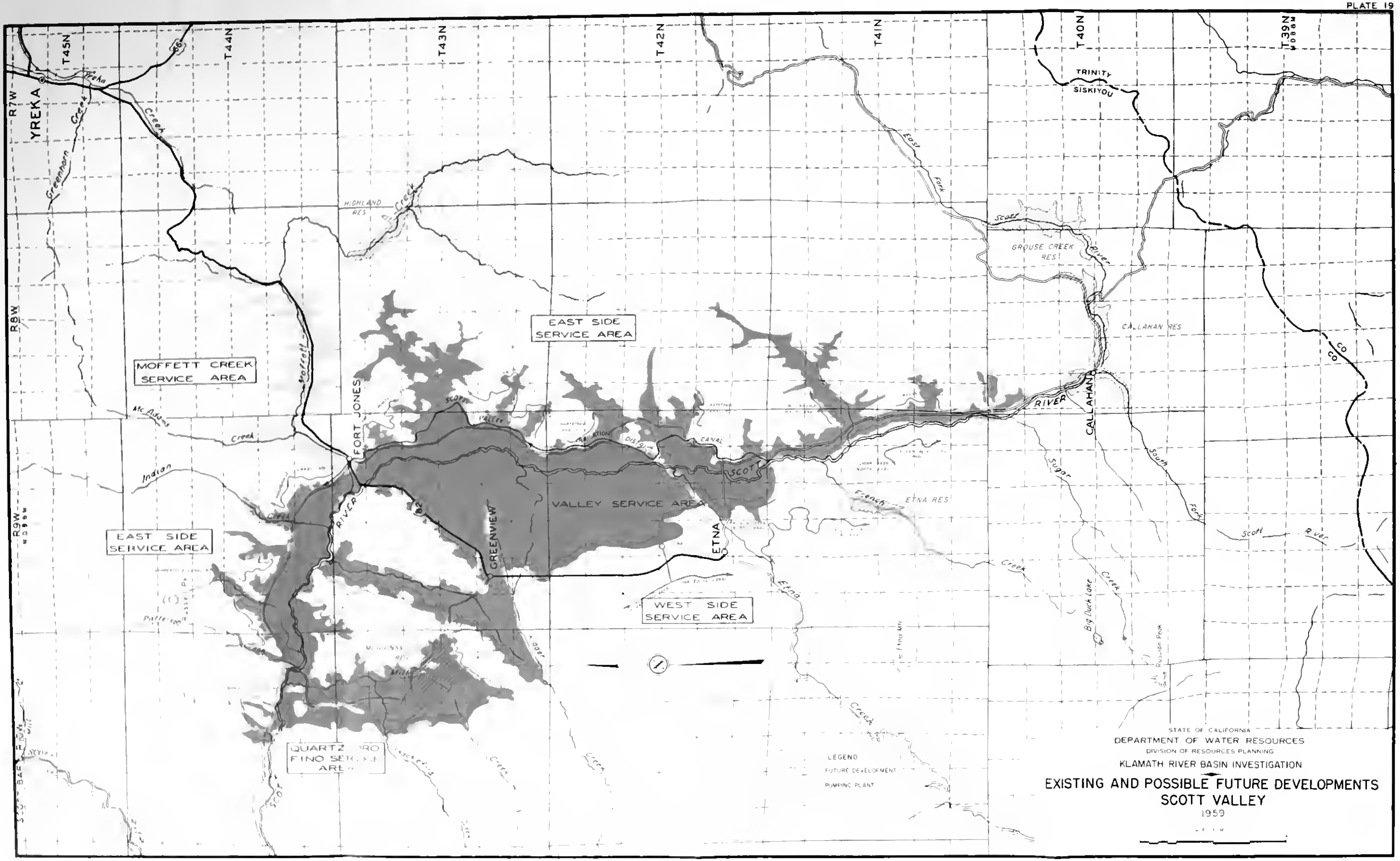
EXISTING AND POSSIBLE FUTURE DEVELOPMENTS, UPPER KLAMATH RIVER BASIN

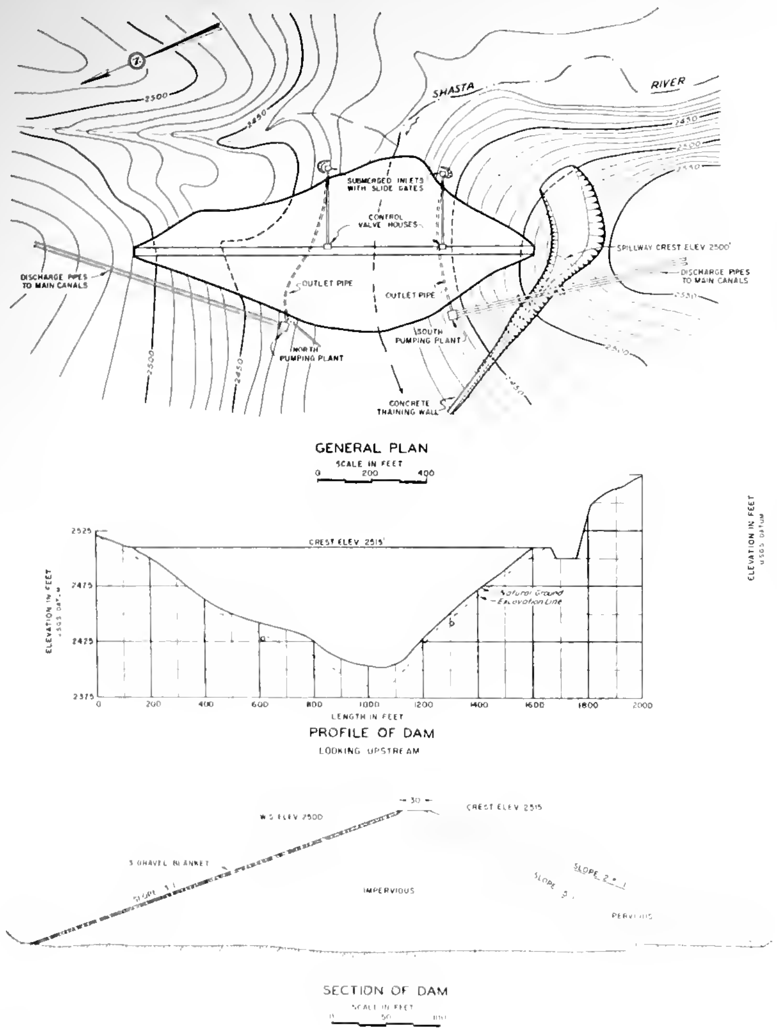
1959

PLATE 18



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
KLAMATH RIVER BASIN INVESTIGATION
EXISTING AND POSSIBLE FUTURE DEVELOPMENTS
SHASTA VALLEY
1959
SCALE OF MILES
LEGEND
EXISTING DEVELOPMENT
FUTURE DEVELOPMENT
PUMPING PLANT
POWER PLANT
WATER SERVICE AREA
T.48N.
T.47N.
T.46N.
T.45N.
T.44N.
T.43N.
T.42N.
T.41N.
T.40N.
R.4W.
R.5W.
R.6W.
R.7W.
OREGON
MT. SHASTA
WEED
EDGEWOOD
GAZELLE
GRENADA
MONTAGUE
YREKA
KLAMATHON
HORNBROOK
HENLEY
AGER
HILT
KLAMATH
SHASTA
RIVER
Little Shasta River
Shasta River
Willow Creek
Bogus Creek
Little Bogus Creek
Deer Creek
Slide Creek
Cottonwood Creek
Yreka Creek
Parks Creek
Parks Ditch
Oregon Slough
Bump
Steam Boat
Black Butte
SOUTHERN PACIFIC
SISKIYOU
TRINITY
99
97


T45N
T44N
T43N
T42N
T41N
T40N
T39N
R7W
R8W
R9W
YREKA
Greenhorn Creek
Yreka Creek
TRINITY
SISKIYOU
HIGHLAND RES
East Fork
Scott River
GROUSE CREEK RES
CALLAHAN RES
EAST SIDE SERVICE AREA
MOFFETT CREEK SERVICE AREA
Moffett
McAdams Creek
Indian Creek
FORT JONES
SCOTT VALLEY IRRIGATION DISTRICT CANAL
RIVER
CALLAHAN
South Fork
Sugar Creek
French Creek
ETNA RES
VALLEY SERVICE AREA
GREENVIEW
ETNA
EAST SIDE SERVICE AREA
WEST SIDE SERVICE AREA
Etna Creek
Big Duck Lake
Russian Peak
Scott River
QUARTZ VALLEY ... SERVICE AREA
LEGEND
FUTURE DEVELOPMENT
PUMPING PLANT
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
KLAMATH RIVER BASIN INVESTIGATION
EXISTING AND POSSIBLE FUTURE DEVELOPMENTS
SCOTT VALLEY
1959



MONTAGUE DAM

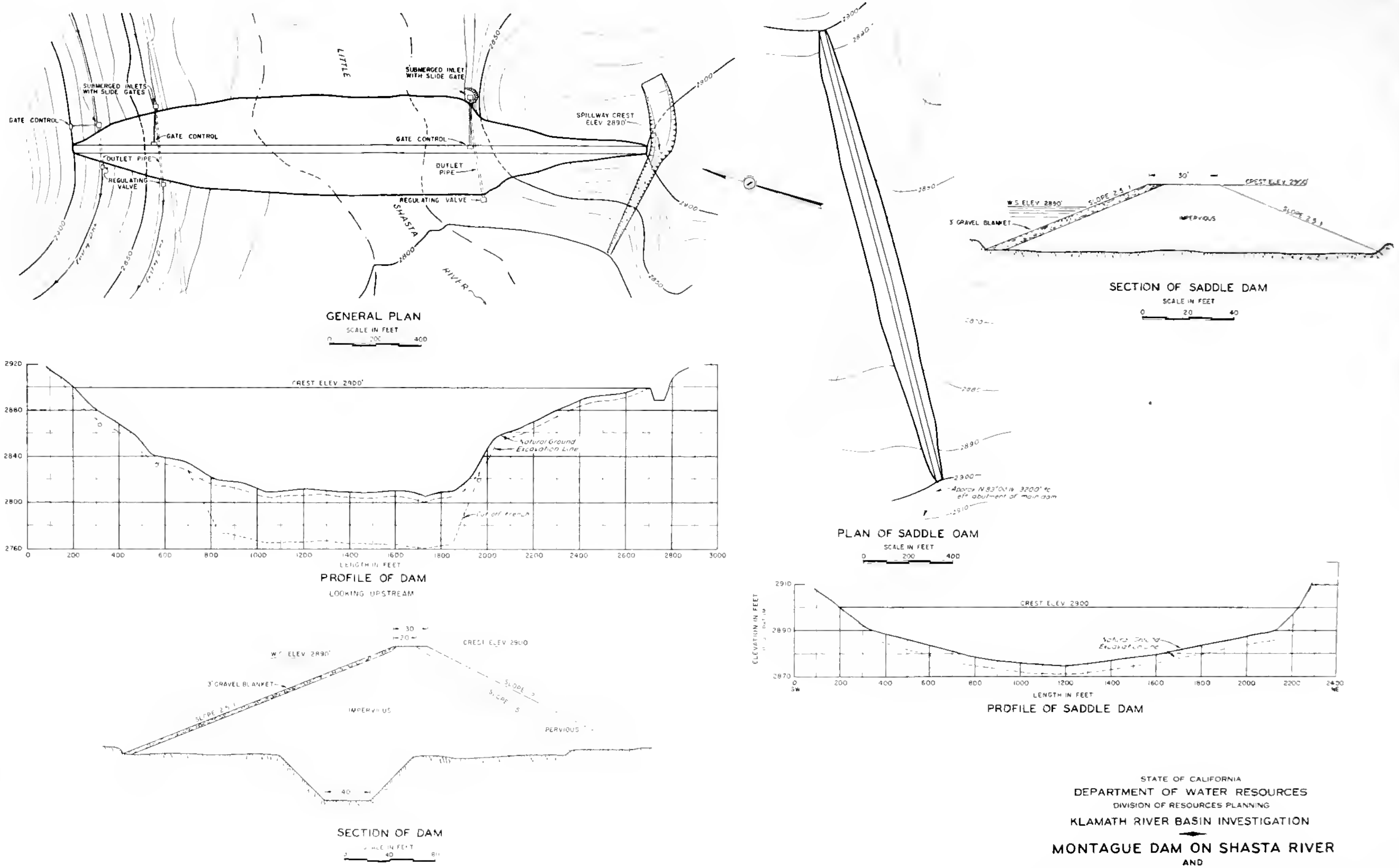
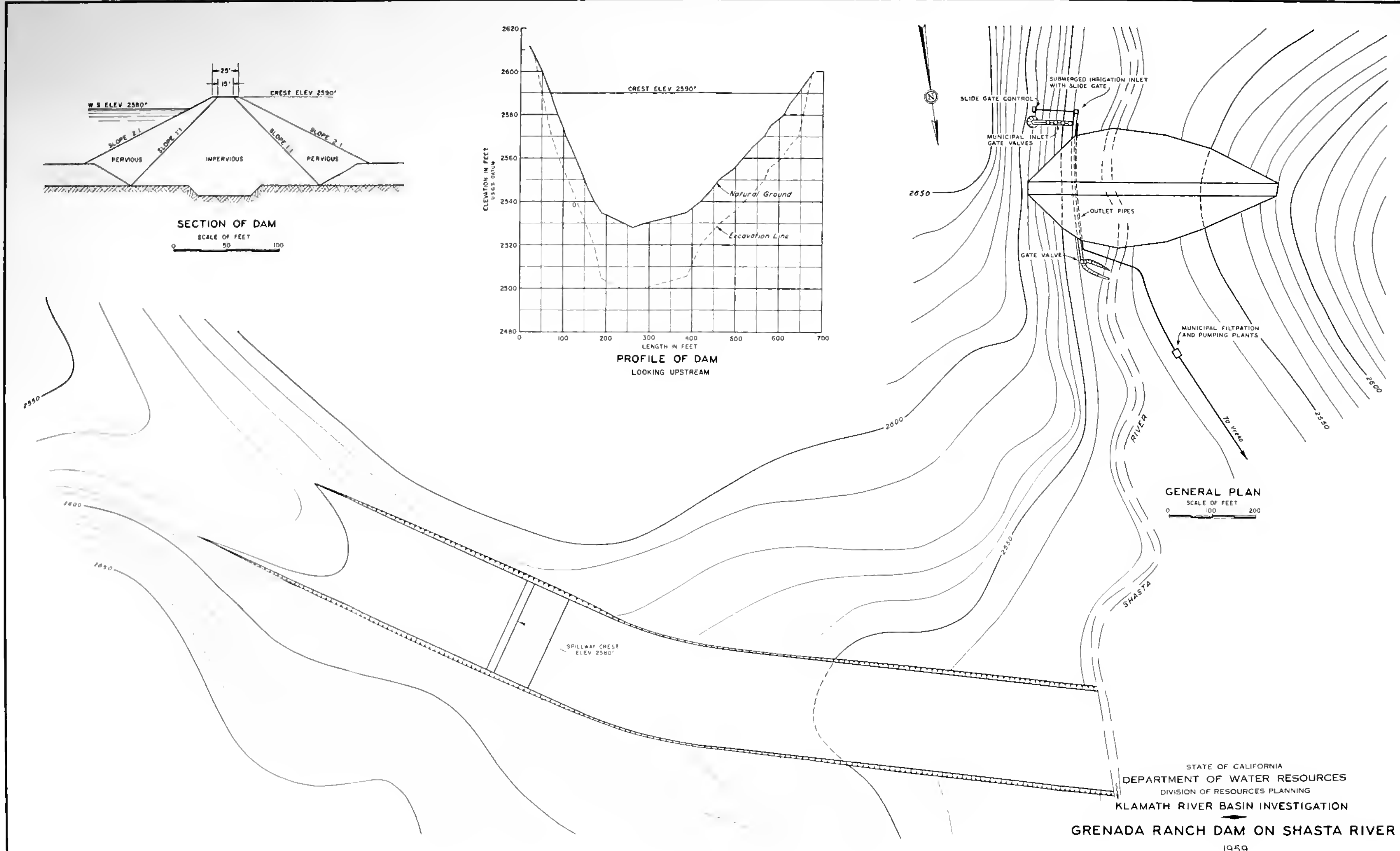


TABLE ROCK DAM

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
KLAMATH RIVER BASIN INVESTIGATION

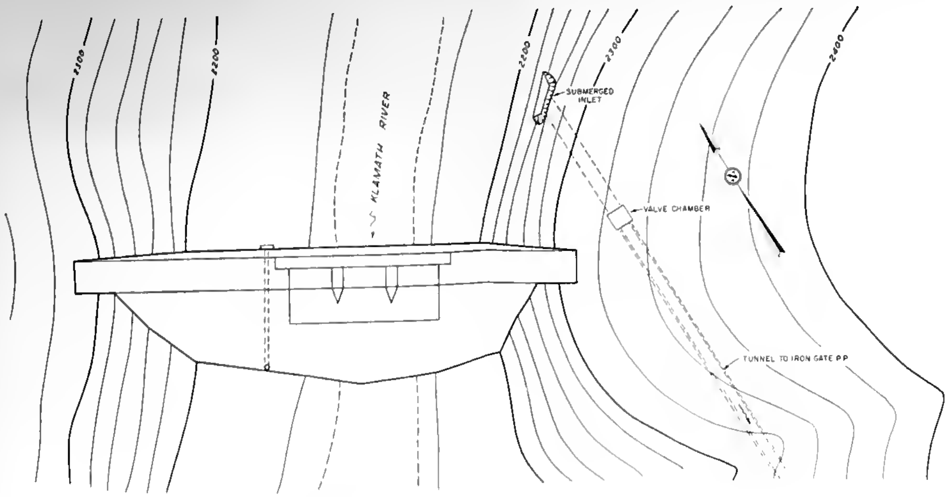
MONTAGUE DAM ON SHASTA RIVER
AND
TABLE ROCK DAM ON LITTLE SHASTA RIVER
1959



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
KLAMATH RIVER BASIN INVESTIGATION

GRENADA RANCH DAM ON SHASTA RIVER

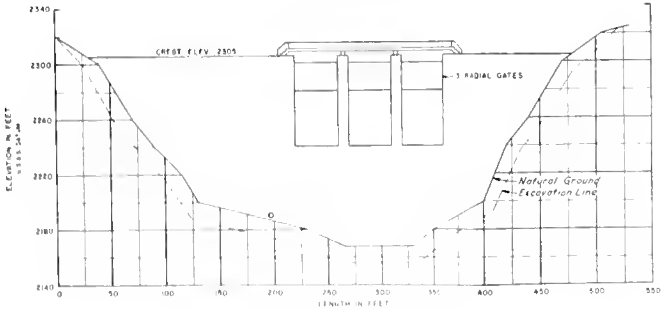
1959



GENERAL PLAN

SCALE OF FEET

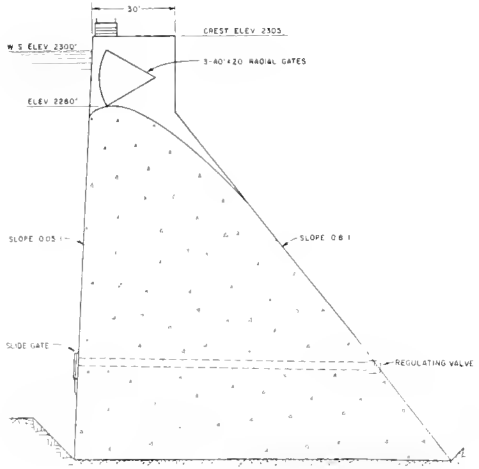
0 50 100



PROFILE OF DAM

LOOKING UPSTREAM

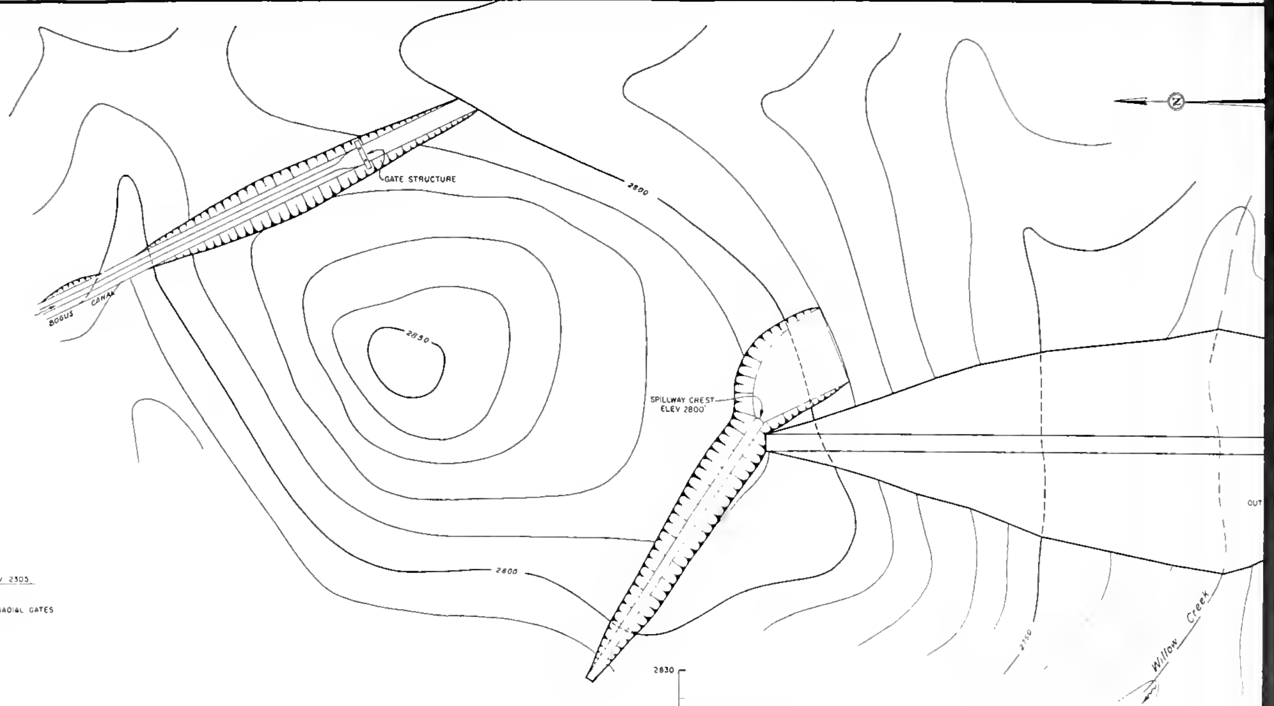
IRON GATE DAM

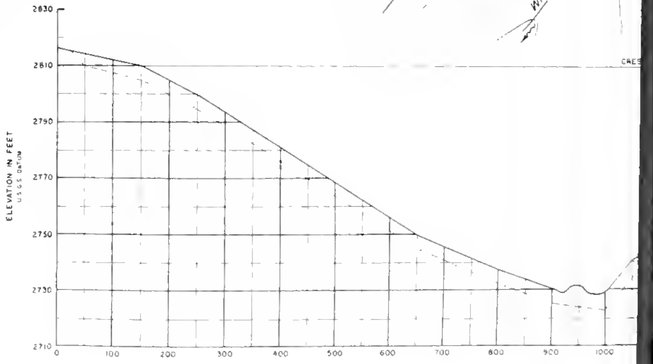


SECTION OF DAM

SCALE OF FEET

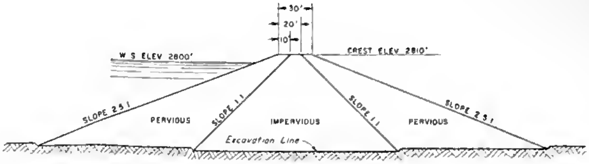
0 20 40





PR

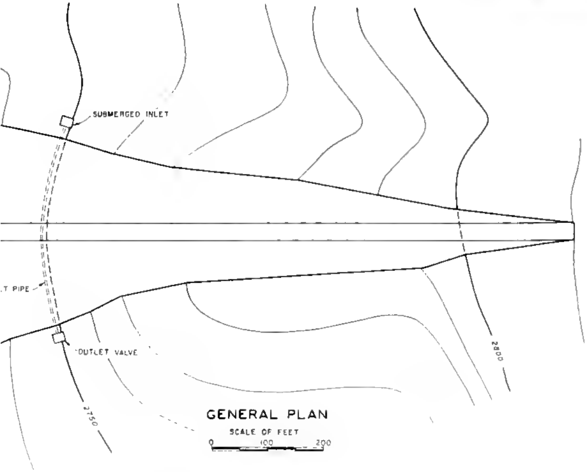
RED



SECTION OF DAM

SCALE OF FEET

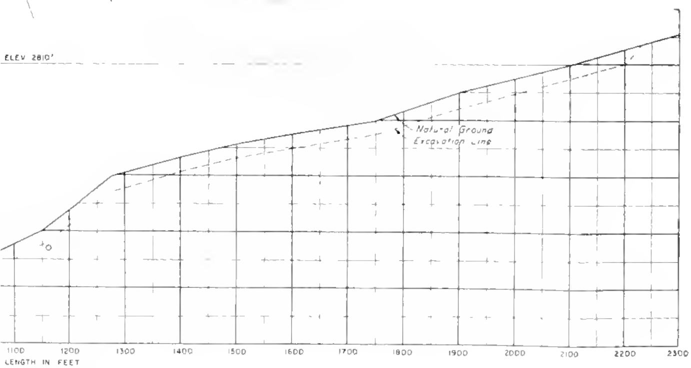
0 50 100



GENERAL PLAN

SCALE OF FEET

0 100 200



OFILE OF DAM

OOKING UPSTREAM

SCHOOL DAM

STATE OF CALIFORNIA

DEPARTMENT OF WATER RESOURCES

DIVISION OF RESOURCES PLANNING

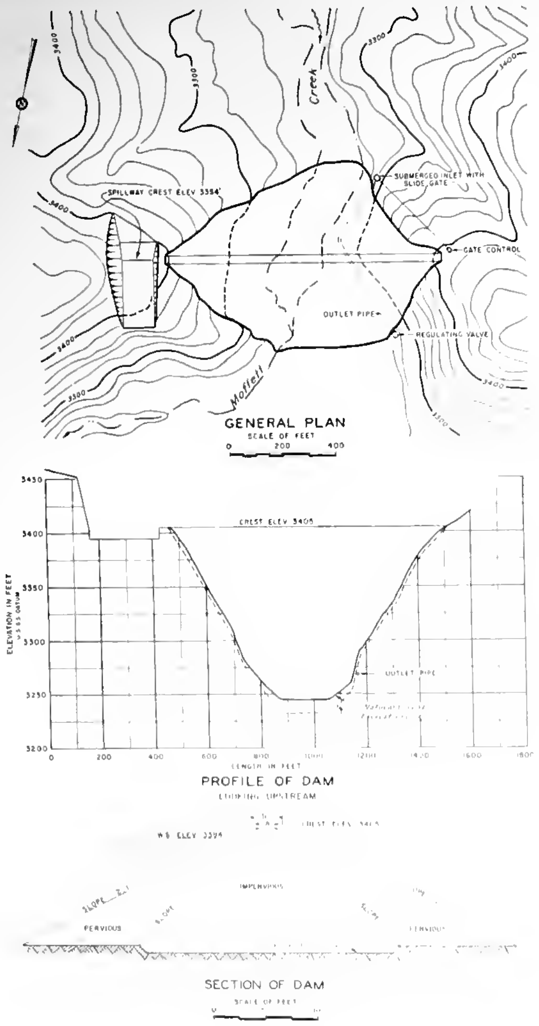
KLAMATH RIVER BASIN INVESTIGATION

IRON GATE DAM ON KLAMATH RIVER

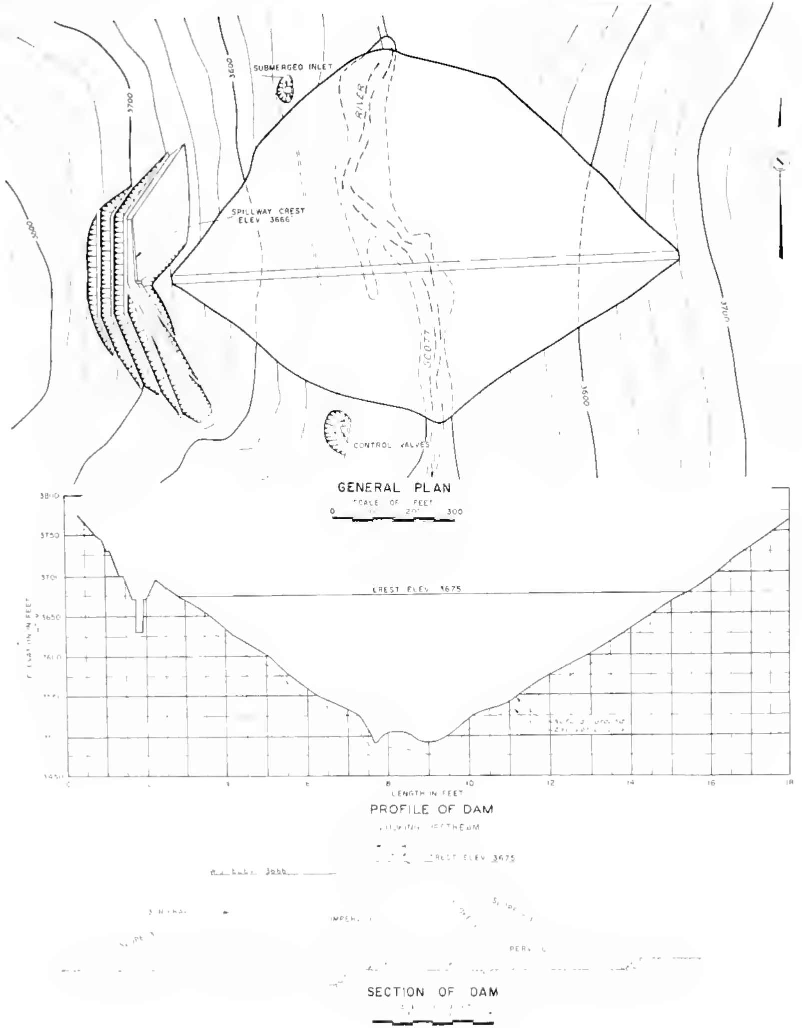
AND

RED SCHOOL DAM ON WILLOW CREEK

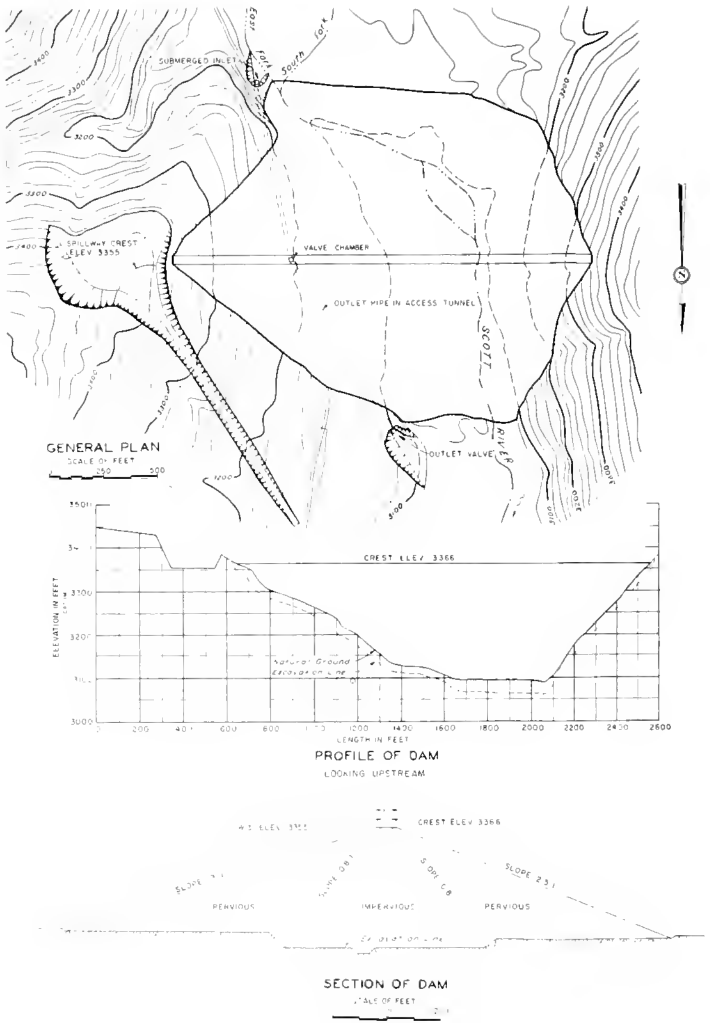
1959



HIGHLAND DAM



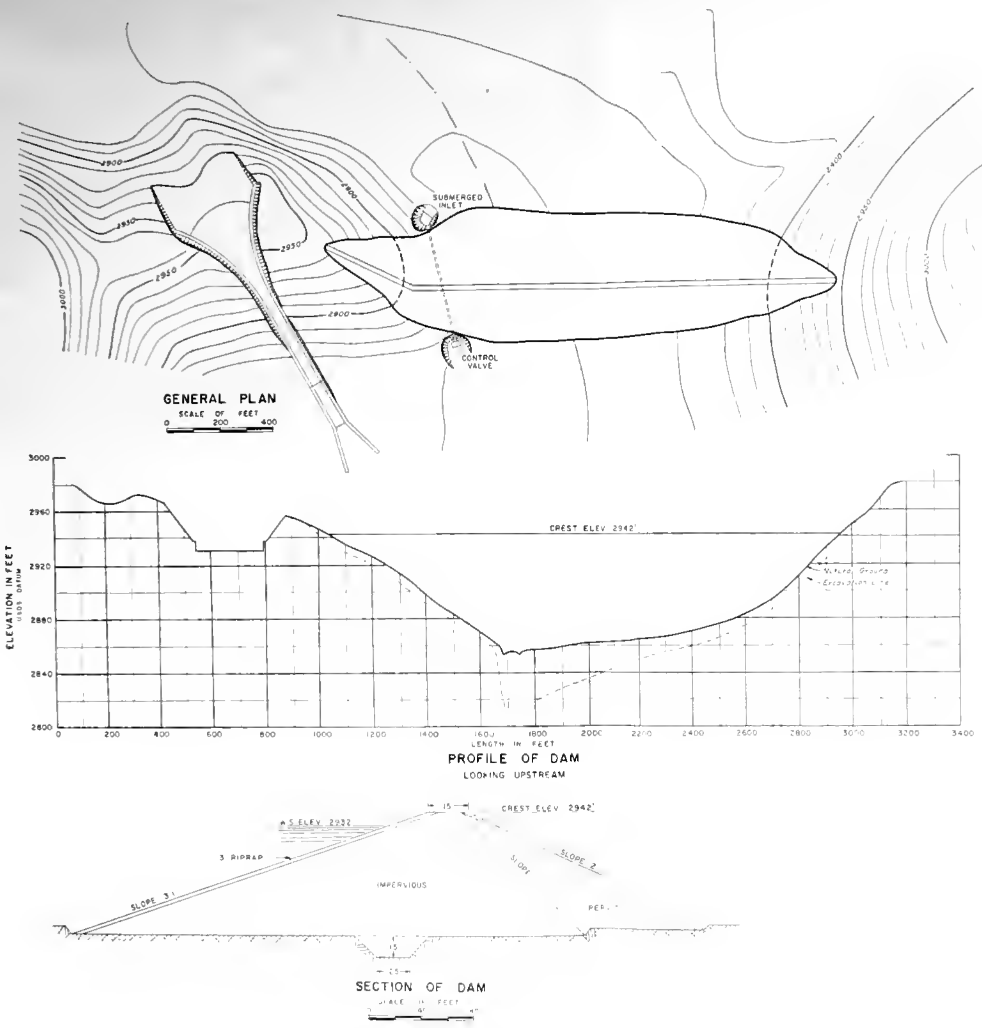
GROUSE CREEK DAM



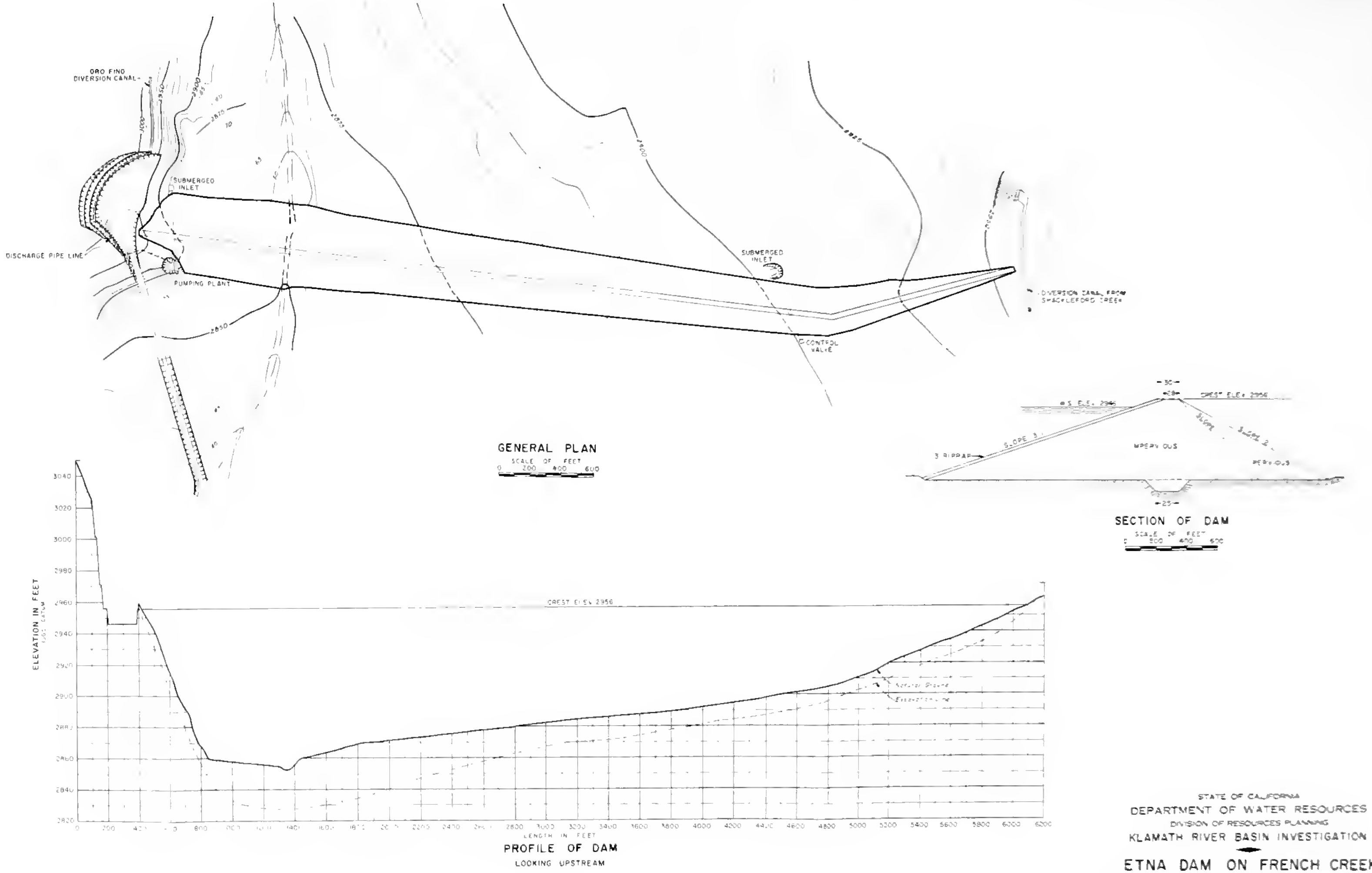
CALLAHAN DAM

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
KLAMATH RIVER BASIN INVESTIGATION

CALLAHAN DAM AND GROUSE CREEK DAM
ON SCOTT RIVER
AND
HIGHLAND DAM ON MOFFETT CREEK
1959



ETNA DAM



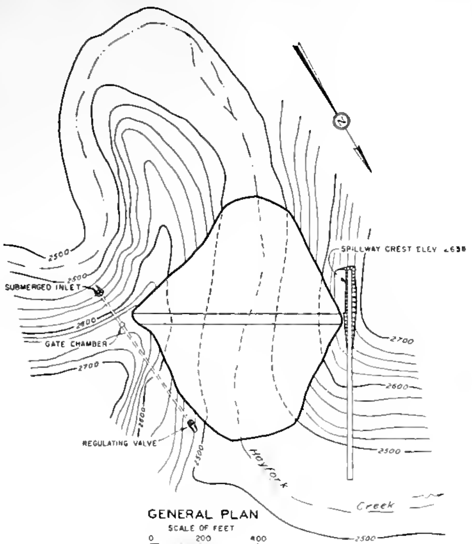
MUGGINSVILLE DAM

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
KLAMATH RIVER BASIN INVESTIGATION

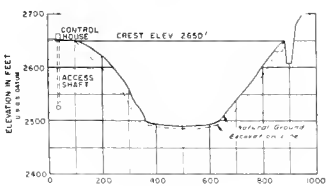
ETNA DAM ON FRENCH CREEK
AND
MUGGINSVILLE DAM ON MILL CREEK

1959

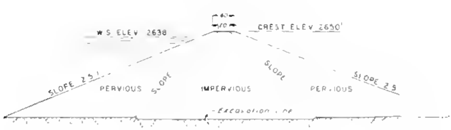
LAYMAN DAM



GENERAL PLAN
SCALE OF FEET
0 200 400



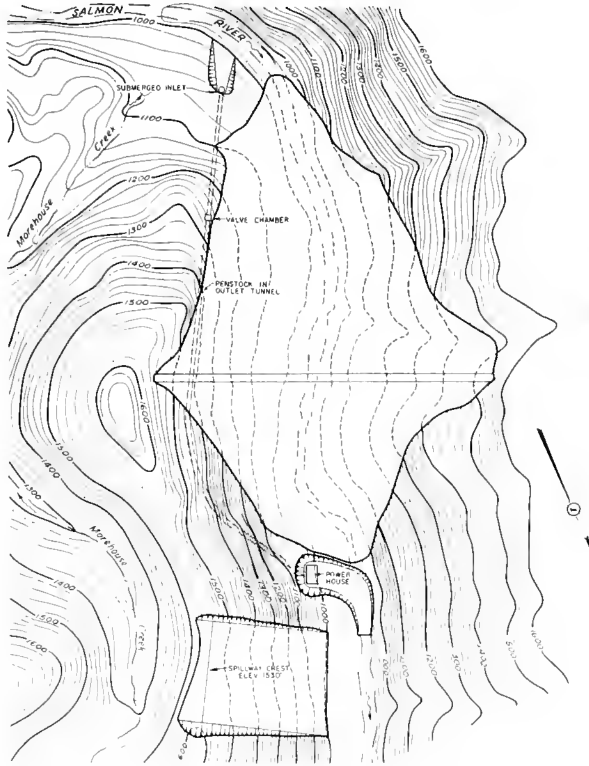
PROFILE OF DAM
LOOKING UPSTREAM



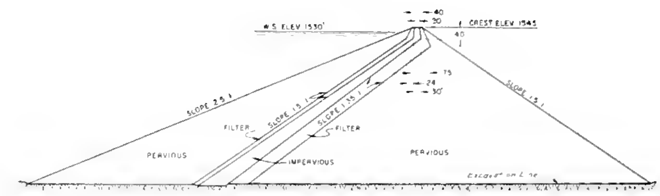
SECTION OF DAM
SCALE OF FEET
0 100 200

LAYMAN DAM

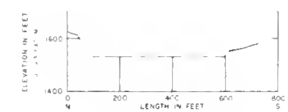
MOREHOUSE DAM



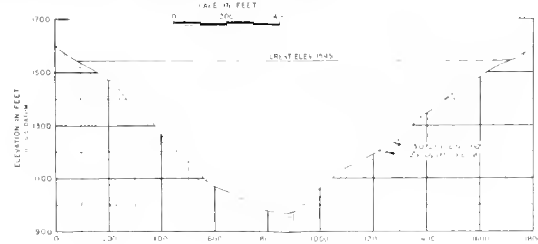
GENERAL PLAN



SECTION OF DAM
SCALE IN FEET
0 200 400



PROFILE OF SPILLWAY



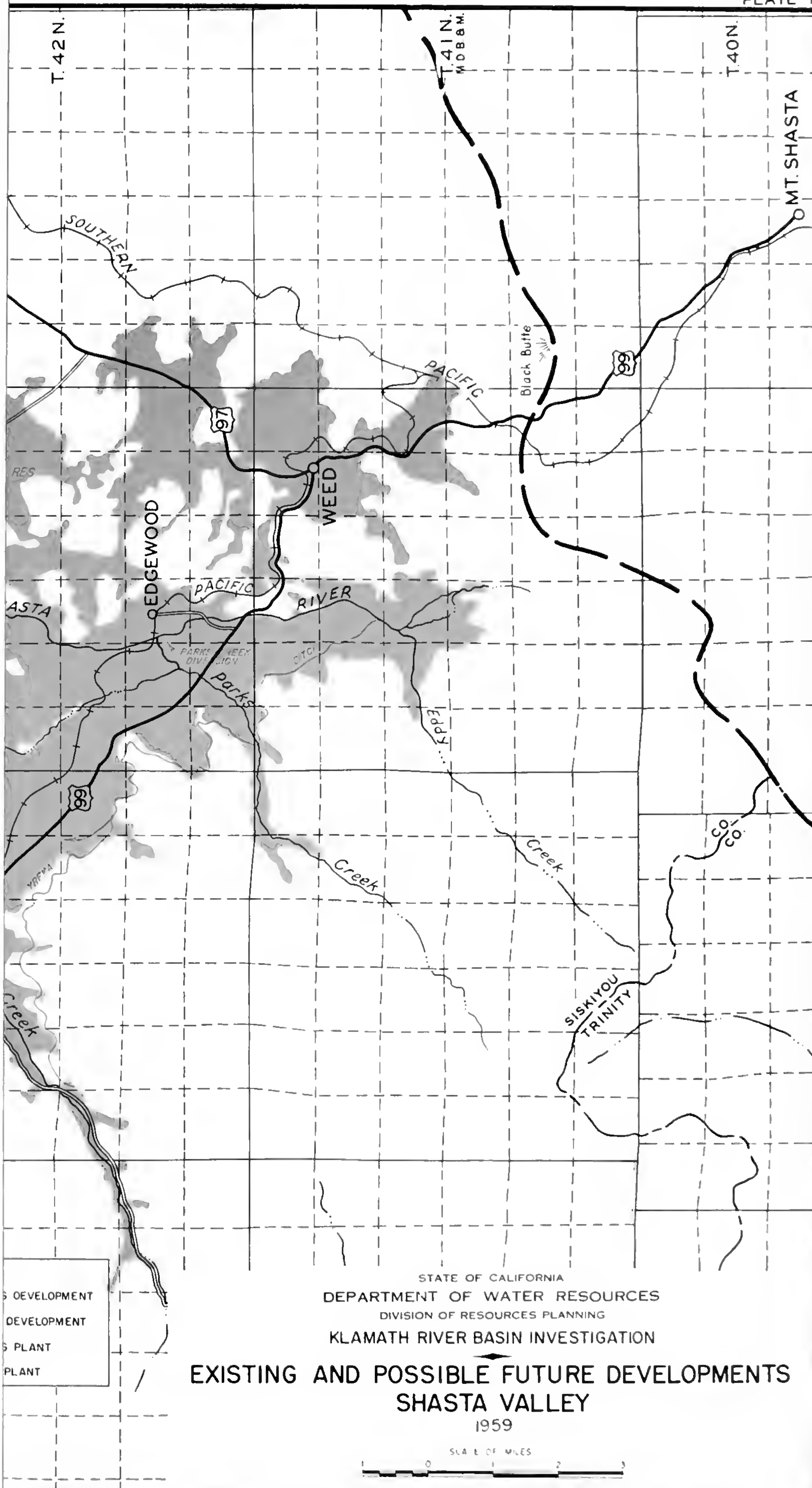
PROFILE OF DAM
LOOKING UPSTREAM

MOREHOUSE DAM

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
KLAMATH RIVER BASIN INVESTIGATION

MOREHOUSE DAM ON SALMON RIVER
AND
LAYMAN DAM ON HAYFORK CREEK

1959



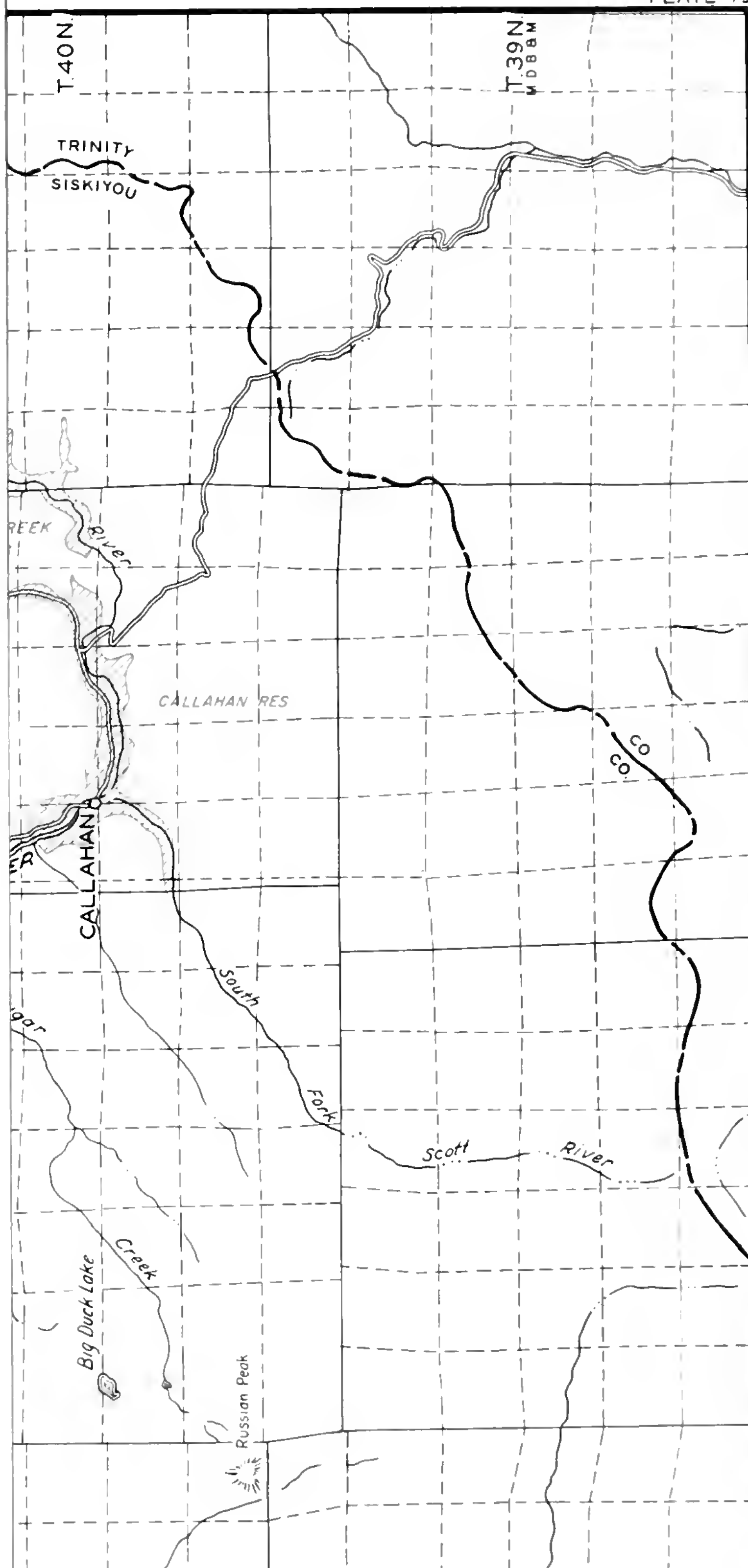
STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
KLAMATH RIVER BASIN INVESTIGATION

EXISTING AND POSSIBLE FUTURE DEVELOPMENTS SHASTA VALLEY

1959

SCALE OF MILES

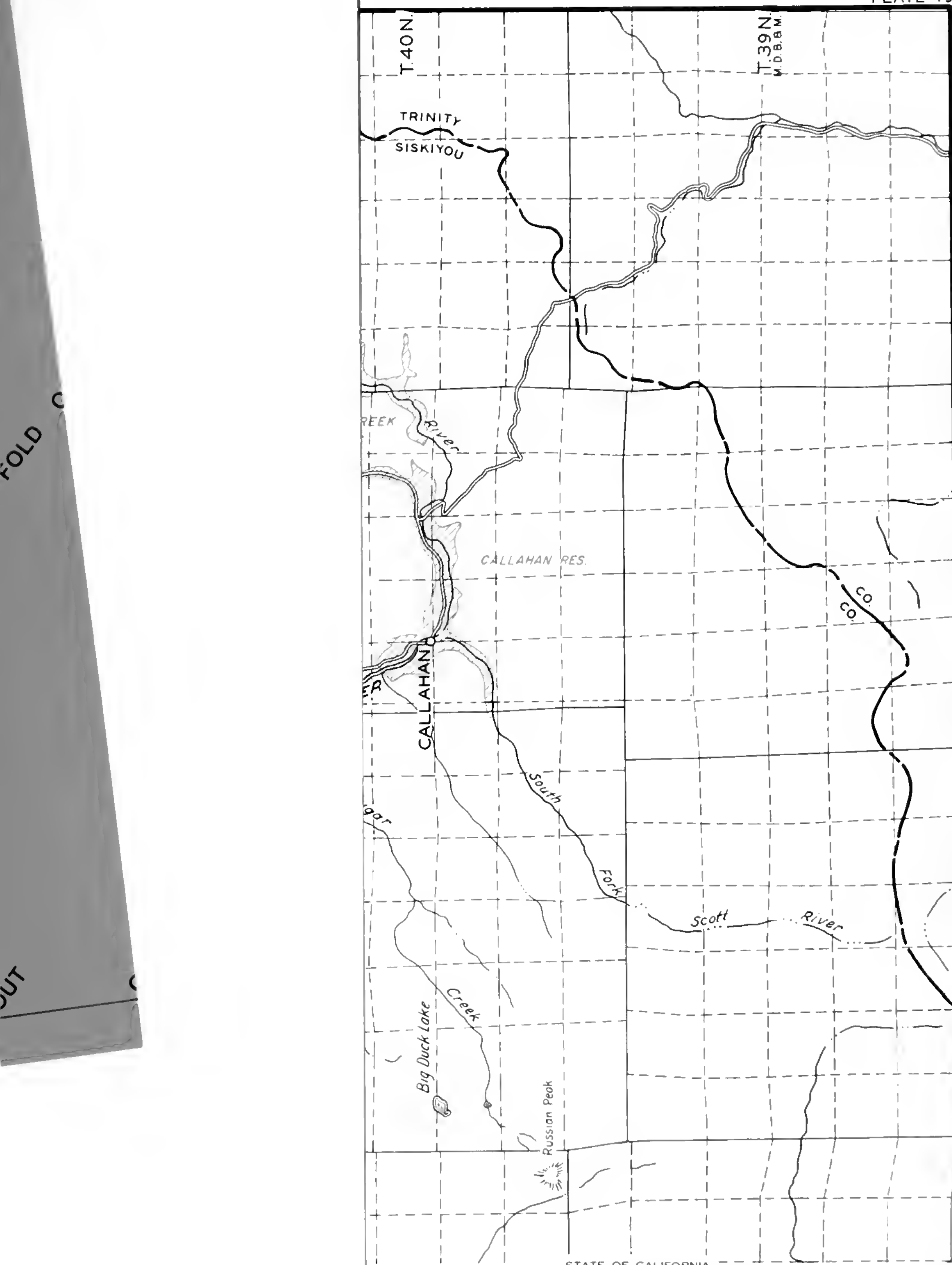
1 0 1 2 3



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
KLAMATH RIVER BASIN INVESTIGATION

XISTING AND POSSIBLE FUTURE DEVELOPMENTS
SCOTT VALLEY
1959

SCALE OF MILES



STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING
KLAMATH RIVER BASIN INVESTIGATION

XISTING AND POSSIBLE FUTURE DEVELOPMENTS
SCOTT VALLEY
1959